ACCELERATION OF U.S. TECHNOLOGY UTILIZATION AND COMMERCIALIZATION

HEARING

BEFORE THE

SUBCOMMITTEE ON
TECHNOLOGY AND COMPETITIVENESS

OF THE

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CONTENTS

WITNESSES

Page

May 7, 1991:

Dr. Bruce Guile, Director, Program Office, National Academy of Engineering, Washington, DC; Dr. William R. Boulton, Olan Mills Professor of Strategic Management, and Director, Center for International Commerce, Auburn University, Alabama; Charles A. Eldon, Past President and Elected Fellow, Institute of Electrical and Electronics Engineers, Washington, DC; and Richard J. Elkus, Jr., Chairman, Prometrix Corp., Santa Clara, California 3

ACCELERATION OF U.S. TECHNOLOGY UTILIZATION AND COMMERCIALIZATION

TUESDAY, MAY 7, 1991

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:35 a.m., in room 2325, Rayburn House Office Building, Hon. Tim Roemer [acting chairman of the subcommittee] presiding.

Mr. ROEMER. This committee will come to order.

Good morning, and welcome to the Subcommittee on Technology and Competitiveness, the hearing on the Acceleration of U.S. Technology Utilization and Commercialization.

Although the United States is frequently first in innovative scientific discoveries, it has a more difficult time translating innovation into a commercially viable product, getting the product to the marketplace, and then gaining and keeping a market share.

As a consequence, significant U.S. inventions, such as the television, the VCR, and the compact disc player, are mostly manufactured by foreign firms. In contrast, Japan has emerged as an economic superpower, turning these American inventions into billion-dollar industries and producing high quality products which are in demand worldwide. Why? What has brought about the reversal in this fortune?

Last week, this subcommittee held a hearing which compared Japan's government-business relationship to that in the United States in an attempt to determine those factors which have contributed to Japan's commercial success. Today's hearing will build on that record and focus on what steps the U.S. can take to reverse this disturbing trend in U.S. competitiveness. We must stop the erosion in manufacturing jobs which have long been the backbone of this economy.

Our witnesses have broad experience in technology matters. We encourage them to answer today's answers broadly. We, as a new subcommittee, are searching for the areas in competitiveness and technology policy, where legislative action may be necessary either by this subcommittee or by others. We look forward to the testimony of our distinguished witnesses.

I would also like to say before opening up that I would like to thank the chairman, Chairman Valentine, who has been such a leader in this area, for initiating this set of hearings and also for the privilege of conducting this hearing as a freshman Congress-

man. I also would like to welcome my colleagues here this morning that join me in recognizing the important and vital contribution that the subject matter is for us as a competitive nation today, both the hardware issues that we look at in terms of new technology and new investment as well as the software issues. Whether that be the strength of our education system and the investment in human resources, or many of the other matters that I hope our witnesses will pinpoint and hone in on today.

I would welcome opening remarks from my colleagues here this morning.

Mr. ROHRABACHER. Thank you very much.

Chairman Valentine and I were at a hearing in North Carolina yesterday on this subject, and it is, of course, so vitally important that the United States not only have the creative powers and the ingenuity to come up with new products, or the new inventions, but also the ability to put those new inventions and those new ideas into products and to actually make sure that our ingenuity is helping us be competitive and productive so that we can be actually beating the world competition, and I was very impressed by what I saw in North Carolina, and what is going on there in the Raleigh-Durham area is just mind boggling.

I told a story down there about the Soviets and how they were so impressed with the computers at a food store and the bar code and then come to find out that that was designed and developed right there in North Carolina in the Raleigh-Durham area in this industrial-scientific park.

I think that we have got a lot of things to look at in terms of actual utilization of our scientific knowledge. There has got to be some flaw in our system when we invent things and the Japanese put them to use. There has just got to be some flaw there, and this has happened over and over again, and it is time we looked at this and we started talking about some fundamental reform that will permit the United States to get the full advantage of the creative genius of our own people.

So I appreciate this hearing and am looking forward to your leadership, Mr. Chairman, your new leadership.

Mr. ROEMER. Thank you, Mr. Rohrabacher.

Mr. Thornton from Arkansas.

Mr. THORNTON. Mr. Chairman, I would like to congratulate you on chairing this set of hearings. Chairman Valentine recognizes real talent and leadership, and I want the witnesses to know that you have been a leader in suggesting the need for a comprehensive, cohesive strategy for improving our ability to manufacture high technology goods here rather than seeing the inventive genius slipping overseas and providing better jobs to other countries. I congratulate you on that leadership.

But we are also very privileged in the panel of witnesses that we have today. I have known several of these gentlemen for some time. They represent disciplines that will be very important in this most important work, and I am particularly glad to see people from Auburn. My predecessor, Jim Martin, left the University of Arkansas to allow me to become its president, and I understand he is now stepping aside from Auburn; and Dr. Guile, it is a pleasure to see you; Dr. Eldon; and my good friend, Richard—Dick—Elkus,

it is an honor to see you before us. I am looking forward to hearing your testimony. I have read the material that you have submitted, but I am looking forward to the conduct of this hearing by our able chairman, Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Thornton, and if you are looking for a favor from the chairman, you know the system well. I can tell you have served here before, Mr. Thornton. You have done a good job of introducing the witnesses as well, too.

Mr. THORNTON. Oh, I didn't mean to—

Mr. ROEMER. That is quite all right.

If we would care to start, please. I am not sure that I need to introduce the witnesses after those articulate and eloquent remarks from my colleague from Arkansas, but I will anyway. Dr. Bruce Guile, the Director of the Program Office of the National Academy of Engineering—welcome this morning—Dr. William R. Boulton of the Strategic Management—the Olan Mills Professor of Strategic Management—excuse me—and the Director of the Center for International Commerce—welcome, Doctor—Mr. Charles Eldon, past President and the Elected Fellow, the Institute of Electrical and Electronics Engineers—welcome this morning—and Mr. Richard Elkus, as Mr. Thornton just introduced you, sir.

Welcome this morning, and if you would care to start—Bruce, if you would like to.

STATEMENTS OF BRUCE GUILE, DIRECTOR, PROGRAM OFFICE, NATIONAL ACADEMY OF ENGINEERING, WASHINGTON, D.C.; WILLIAM R. BOULTON, OLAN MILLS PROFESSOR OF STRATEGIC MANAGEMENT, AND DIRECTOR, CENTER FOR INTERNATIONAL COMMERCE, AUBURN UNIVERSITY, ALABAMA; CHARLES A. ELDON, PAST PRESIDENT AND ELECTED FELLOW, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, WASHINGTON, D.C.; AND RICHARD J. ELKUS, JR., CHAIRMAN, PROMETRIX CORPORATION, SANTA CLARA, CALIFORNIA

Dr. GUILE. I would like to thank the committee for the opportunity to appear here today, and I have submitted my full statement for the record, and I would like to just take a few minutes, if I could, to summarize what is there.

I would like to note that what I am going to talk about today is based on a three-year study by the National Academy of Engineering that was chaired, or is being chaired, by William Howard, Junior, who is a senior fellow with the Academy and former senior vice president and director of research and development at Motorola. The report, which is in its final phases, will appear this fall, published by the Free Press. I didn't bring a 1-800 number, but it will be commercially published this fall, and it is titled "'Profiting from Innovation."

I would also like to emphasize that I am speaking on my own behalf, and it is based on my work as director of the study, and I am not speaking for the study committee members, the Academy of Engineering, its officers, or members.

I will say that the study effort sprang from exactly the realization that is reflected in the prospectus for this hearing, the perception that U.S. companies were consistently failing to bring success-

ful commercial products out of what appears to be the world's most preeminent scientific and engineering enterprise, and over the last three years I will say that the study has focused primarily on private management approaches to commercializing products, not on the Government policy questions, but we can come to that a little bit later.

What I would like to do first is to summarize—primarily is to summarize a working framework of three different categories of commercialization that are very important to understanding the diversity of approaches necessary to managing it, but first I have to tell a remarkable and wonderful story about commercialization of a particular product.

One of the committee members was Robert Sharpey who was a former chairman of Cabot Corporation, and he tells a terrific story about sitting in his office and having a lab scientist come in and say that he had invented the world's best energy absorbing polymer, and he held up two balls, one of them rubber and one of them made out this new material, and dropped them, and the rubber ball bounced, and the energy absorbing material did not, it just fell to the floor, and Bob Sharpey asked, "What shall we do with this?" and the scientist said, "That was your problem"—you know, as leader of the corporation, he had to figure it out.

So they went back to the laboratory, and there was great enthusiasm for the invention but not a whole lot of information about what to do with it, so they foamed a bunch of it up and turned it into a very spongy material, they cut it into the size of coffee cups, and they were sitting in the conference room one day, and somebody squeezed one of the coffee cup size pieces and watched it slowly expand into or back to its original state, and all of a sudden the light bulb came on and somebody thought, "Ear plugs," and the last time I checked, Cabot Corporation owned 80 percent of the world market for ear plugs, using this very high-tech material.

Now just to prove—to verify personally that this is the case, when I was last in Japan, I went to the Japanese airport, and here you have a U.S. manufactured produce marketed in Japanese and proudly labeled, "Made in the U.S.A., a Cabot Corporation product." So, in spite of the fact that there are all sorts of disasters, there are lots of examples of effective commercialization.

Now, I also wanted to tell that story for a very, very specific reason. It is a wonderful story. I mean it is a remarkable success, and it is as true as I can tell it, given that I have heard it through second-hand sources at this point. I also want to say it is a terrible, terrible conceptual model for thinking about commercialization. It is the standard model that people think about: Some smart scientist comes out of the laboratory with a great idea, and all of a sudden it turns into a wonderful commercial success. It is so burned into the brains of most people who think about this process that it is very hard to get away from it. But I think that if we find ourselves trapped in thinking about scientific discovery translating that easily into commercial success, we are going to fail on an ongoing basis, and I think that is part of what has happened with U.S. companies in the last years.

Following up on that, it is important to say that technology is rarely clean and external to a business. It is rarely received from

outside in a pure form. It is mostly a matter of basic business exercise. It is as fundamental to the business function as is personnel management or keeping good records. There is no way to separate the management of technology in any effective way from the management of the business operation itself, and, stepping up to that, I would like to briefly illustrate the four different types of commercialization that were revealed by the study process which I think—the categories are loose, but they give a good illustration of the different types of challenges that companies face.

The first type of challenge is the technology-driven commercialization. That is, somebody goes into a laboratory and indeed does invent something. As with the example with the ear plugs, it happens, but not as frequently as you would think and certainly not enough to sustain a national economy the size of the United States. The most important sort of risk factors at that point are that, when you have developed something without a market, the real risk comes in trying to ascertain whether or not there is a fit between the technology and the marketplace.

The second type of challenge is what we call the new market-driven commercialization, which is taking an existing technology, something that is relatively well understood and worked over in the laboratory or in the development of other processes and moving that technology into a new marketplace. The example that appears in my full testimony is from the Bell and Howell Corporation, a very interesting story.

They were the world's largest publisher of microfiche, and General Motors asked them to get into the business of automating parts catalogues for the repair facilities of auto dealerships, a real challenge. The catalogues are 16 linear feet of information about all sorts of different cars, and they went through a long iterative search of trying to bring better information to the parts dealer who is trying to handle and control the system from the catalogue, or from the counter, and they finally settled on a CD-ROM-based system which essentially allowed instant access to the information.

Now Bell and Howell didn't make any of the technology themselves. They made virtually nothing, but they packaged very effectively an existing technology or set of technologies for a new market, and that is a very important type of commercialization, which is quite different from taking something that was invented in the laboratory to the marketplace.

The third type of commercialization is what the committee called product and process improvement commercialization, and it is the incremental improvement of existing products and processes to the point where they are dominant, and this is where many Japanese companies have a well earned reputation in moving through the product cycle much faster than their American competition, getting a few months' lead for one generation, a few months' lead for the next generation, and the cumulative effect of that is extremely powerful in the marketplace. Ralph Gomory, formerly with IBM and now of the Sloan Foundation, has written very interesting material about this, and it is widely available.

Then the fourth category of commercialization is what the committee called the end game, which is essentially; the market is saturated; virtually all of the purchases are not new applications

but are replacements; and the question that the company faces is, how much of an investment should it make in what is now a mature product line? How much can they ring sort of a profitable product out of what is likely to be a crowded market? And there are a lot of very significant technical questions to be answered at that point.

While it would seem that all business managers would understand these things, it is obviously not the case, and I would like to illustrate the persistence of this problem by citing a 1967 report which was chaired by the same Robert Sharpey who was then president of Union Carbide Electrics—or Electronics, rather, and those who are scholars of technology policy history will recognize the Sharpey report. It is very similar to the kinds of reports that we have seen over the last five or six years about technology and competitiveness with one important exception: 1967 was well before foreign competition had become quite so prevalent, and, as a result, while the report mentions tax policy, and venture capital, and antitrust, and regulation, and Government contracting, it says almost nothing significant about international trade.

But what amused me was the final recommendation. The report is titled "Technological Innovation: Its Environment and Management," and I'll read this brief final recommendation verbatim. "One more recommendation remains, and it is, in our view, of key importance. We have stressed the reason for it throughout this report. It has little to do with the abundance of ignorance about the processes of innovation, invention, and entrepreneurship, but whether we talk about the problems and contributions of a large or small company, a regulated or unregulated industry, or an individual investor or entrepreneur. There is too little appreciation and understanding of the process of technological change in too many crucial sectors, including the Federal Government, industry, banks, universities, and cities, and other regions.

More important, therefore, than any specific recommendation concerning antitrust, taxation, the regulation of industry, or venture capital is one central proposal: the major effort should be placed on getting more managers, executives, and other key individuals both in and out of Government to learn, feel, understand, and appreciate how technological innovation is spawned, nurtured, financed, and managed into new technological businesses that grow, provide jobs, and satisfy people."

That was 1967, and while the world has changed dramatically, I think our progress at making a dent in people understanding the process of innovation has not really moved forward very quickly, and the recommendation, in my judgment, still holds today.

Thank you very much.

[The prepared statement of Dr. Guile follows:]

STATEMENT

OF

BRUCE R. GUILE

DIRECTOR, PROGRAM OFFICE

NATIONAL ACADEMY OF ENGINEERING

AT A HEARING ON

ACCELERATION OF U.S. TECHNOLOGY UTILIZATION

AND COMMERCIALIZATION

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

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Profiting from Innovation

The work described here is drawn from a National Academy of Engineering (NAE) study of U.S. industrial commercialization: the translation of innovative ideas into marketplace success as profitable products, processes, and services. The book that reports on the study -- to be published this fall by The Free Press -- is titled **Profiting from Innovation**, co-edited by committee chair, William G. Howard, Jr., NAE Senior Fellow, and Bruce R. Guile, Director, NAE Program Office.

Many factors influence industrial competitiveness. Some, such as the macroeconomic environment and the legal and regulatory systems, are determined primarily by forces external to companies vying for places in world markets. Other factors are internal. Two internal competencies, manufacturing skill, and the effectiveness with which individual firms translate technical innovations into marketplace advantage, are complementary and lie at the heart of efficient industrial practice. Since private companies form the front line in the contest for share of world markets, success at practicing manufacturing and using the entire range of innovation available to the company is an important factor in a nation's industrial competitiveness.

The manufacturing successes of Japanese companies, leaders in many world markets, have been well publicized. Practices such as just-in-time inventory management, quality circles, and total quality management have been embraced by many U.S. and European company managers. In other words, leading U.S. manufacturers have come to realize that they have serious manufacturing problems, and are beginning to address them.

U.S. companies have not been as responsive to the need for improvements in commercialization, the need for improvements in their ability to design and introduce very attractive products that can capture the purchasing dollars of many customers. Unlike the case with manufacturing, U.S. industry has not shown a widespread appreciation for its commercialization shortcomings, and many firms still retreat to the observation that Americans are still the most inventive people on earth. That may be true -- but translating that inventiveness into better production processes and marketed products is essential if U.S. companies are to turn technical advances into industrial strength and economic growth. Microelectronics, gene splicing, computer communications, and efficient airfoil design are great technologies. Products based on these technologies, however, are what provide competitive edge.

The Study

Commercialization success is defined in terms of five attributes that apply equally to products, manufacturing processes, and services: timely market entry, appropriate use of technology, customer acceptance, quality, and cost leadership. The study has been a search for techniques of effective management of commercialization that apply across a wide range of industrial circumstances. The study addressed techniques useful for manufactured products, production processes, and services and focused on those practices that seem to distinguish companies who are consistently successful at commercializing from those who have not done as well.

The study--performed by a committee of National Academy of Engineering members--has been conducted as a series of worksnops where senior managers discussed aspects of their commercialization experience, both good and bad. Several additional interviews supplemented the workshop results. Participant experiences covered about 40 firms of all sizes, plus the financial community, business schools, consortia, U.S. government, and independent research institutes. A few European and Japanese experiences were sought, besides U.S. perspectives, for comparison.

The study makes no pretense of being comprehensive; the goal was to identify those practices that characterize successful commercialization in the broadest possible spectrum of enterprises. Many successful techniques, which apply to particular companies or industries, did not survive the winnowing process that the methodology employed.

As expected, the study process has discovered no magic bullets. The findings reemphasize the importance of the fundamentals of business management -- of a leadership preoccupation with producing a better product or service with higher quality at a lower price than anyone else. These are preliminary results, as the report itself is still in preparation. Regrettably, there is not enough time to describe all of the study's conclusions, so we have selected some fundamental observations.

The Prepared Mind

Louis Pasteur observed that "Fortune favors only the mind that is prepared." Nowhere is that more true than it is in commercialization management. The study revealed that in commercialization, as in any other complex undertaking, there is no substitute for understanding the basic nature of activities within a business. As discussed below, there are several types of

commercialization processes, each with its own pace, indicators of progress, organizational approaches, and risk factors. Understanding when each of these is under way, and the nature of the true challenges faced, is a major factor in consistently successful efforts.

Intimate understanding of both customer needs and technological potentials is essential if the two are to be mated in a successful new product or process. Finally, successful commercialization leaders are constantly reexamining their businesses, always seeking the "better way" that must lie out there somewhere. They continuously reevaluate their activities. The ideal of a "detached manager" capable of overseeing any business strictly at arm's length does not appear to apply to successful commercialization leaders.

Types of Commercialization Efforts

The study uncovered four distinct types of commercialization, distinguished according to their driving forces. Each has unique characteristics, each is measured according to different analytical tools, each has a different characteristic pace, and each requires its own management techniques for successful application.

Technology-driven commercialization is driven by a revolutionary scientific or technical discovery. Rarely is technology revolutionary. Developments such as the transistor, dry copying, certain pharmaceuticals, the industrial robot, nylon, perhaps someday cold fusion or room-temperature superconductors, are singular events. They sweep away the old ways and replace them with entirely new products and processes whose expanded capabilities were previously unimaginable. Yet such revolutionary new technologies rarely live up to expectations initially.

Development of successful products embodying dramatic new technological breakthroughs takes typically fifteen to twenty years and entails a great deal of risk as the basic idea is reduced to practice through a host of supporting technological developments, developments without which the "revolution" is nothing more than a curiosity. Only after this long investment in time and resources is the enormous market potential of such developments realized. While important, a major industrial nation cannot depend principally on technical revolutions. They occur infrequently, entail a level of risk that makes them haphazard, and do not provide the sustained push that an economy must have to endure in the market marathon.

In technology-driven commercialization, the major risk lies in understanding problems entailed in producing the product in volume and in the market for products, much more than in the

technology. Dupont's CORFAM® plastic replacement for shoe leather was a major technological development, and Dupont solved the problems of producing the material in high volume. They reasoned that shoes made of this material were longer lasting, water resilient, less expensive, required less polishing, and were sure to be a market success. They did not correctly appreciate that failure of the shoes to break in to the wearer's feet and the inability of the material to breathe moisture would be problems. These market miscalculations led to the eventual failure of the CORFAM® enterprise.

A flash of brilliance, followed by dogged application of "Yankee ingenuity" to overcome all obstacles is the basic stuff of the American industrial legend. This is where Americans think that their distinctive competence lies. Yet, study participants felt that, as a nation, our grasp of this process is slipping. Accelerating diffusion of basic science and technology around the world, pressures for shorter-term payoff and a general aversion to risk work against success in technology-driven commercialization efforts. This is a problem both in large corporations, where concentration on existing businesses is often the rule, and in small, venture-capital-financed concerns, where the need of financial backers to "cash out" within five to seven years has led to the dismemberment of otherwise promising enterprises.

In addition, financial pressures have led many firms to curtail longer-range research efforts in favor of acquiring technology from outside the company. This strategy, however, plays to a weakness in many American technical efforts -- a seemingly pervasive difficulty in embracing and applying technology developed elsewhere, such as in universities, independent laboratories, and other firms.

Successful practitioners of technology-driven commercialization appear to understand how these projects progress. They are less dazzled by initial announcements of discoveries than they are dedicated to the long, steady pull required to reduce truly new ideas to practice. Often, this is the result of tolerance by stubborn individuals, but a handful of companies consistently make a success of technology-driven innovation through more systematic means.

Although technology-driven commercialization occurs rarely, it is a particularly important part of the overall commercialization activity, for "orthogonal" innovations do not follow logical extrapolation of business growth. When truly successful, technology-driven products, processes, and services not only produce extremely large and rapid business growth, they also make the competition's products or processes (or both) obsolete.

The second commercialization category is <u>new market-driven</u>. In this instance, perception of customer needs in one product

sector prompts a search for technology from other applications to open new opportunities. In market-driven commercialization, the emphasis must be on detailed understanding of the customer's needs and on the selection of the best technology to fulfill those needs. The primary risk element is technological -- choosing the best technology on which to base a product to fill an identified customer need from the wide range of possible alternatives.

The Bell & Howell Company confronted these tasks when they responded to a request from General Motors to apply its skill at microfiche publication to simplify the parts counter catalog used in many dealerships and parts stores. The problem was well known -- looking up parts numbers and prices in existing paper catalogs was a time-consuming effort that resulted in many errors. Further, the daily effort required to keep a comprehensive parts catalog up to date is substantial. Bell & Howell, as the leading publisher of microfiche documents, sought to use its traditional technology to meet the need but discovered that ease of access, document quality, and ability to incorporate illustrations on microfiche were insufficient to provide an attractive alternative. After a five-year search for the best technology fit, and three tries involving microfiche, computer terminals, and a variety of document-storage systems, Bell & Howell settled on a system based on CD-ROM. It not only solved the parts catalog problem at lower cost and provided a continuing publishing business for the company, but enabled the mechanic to specify and order parts directly without going through the parts counter clerk -- a major saving in labor.

The third type of commercialization effort is <u>product- and process-improvement driven</u>. Once a concept has been proven in the market, competition shifts to price, performance, and design features, and less emphasis is placed on fundamental differences in product or service ideas. After one or two initial successes, competitors swarm in quickly, and the focus shifts from making it work to making it work better. The dominant pattern is illustrated by medical imaging equipment, overnight package express, and automated bank teller services that were as recently as 1975 new, different products. These items have now become standard offerings, and early providers and later entrants now engage in competition over incremental improvements in the product or service.

Unlike technology-driven and market-driven cases, success at product- and process-improvement driven commercialization depends upon a company's ability to push incremental innovation in the product design and production process. This is a very different management challenge from running a revolution. This process must be a continuous series of small triumphs. Changes take place rapidly -- in fact the faster the better. In spite of the need for speed, there is little tolerance for mistakes or slipshod work. Stumbling costs irreplaceable time and customer confidence.

Two fundamental issues underlie product- and process-improvement commercialization success -- rapid product cycle time and starting early. As Ralph Gomory--formerly with IBM and now head of the Alfred P. Sloan Foundation--has pointed out, the effect is cumulative. As a company beats its competitors to the market time and time again, its rivals fall ever further behind, less likely ever to catch up.

Continuous product and process improvement does not just happen -- it must be driven by the expectation that such improvement is the basis of future competitive advantage, and must be eagerly sought if the firm is to succeed. U.S. industry's track record at continuous improvement is spotty -- U.S. companies became complacent in the halcyon days of success over the past 40 years. The story of the U.S. steel industry's failure to up-grade its process and plant technology is well known. A number of Japanese companies, on the other hand, have rightly earned their reputation for relentlessly honing their products (such as television sets, cameras, and automobiles) until they drown their competition in a tidal wave of improvements.

One illustration of how this process works is the example of the competition between U.S. and Japanese semiconductor firms for a share of the dynamic random access memory (or DRAM) merchant market. The U.S. semiconductor industry, as inventor of the DRAM, led early with 1K, 4K, and 16K DRAM products. The business became fiercely competitive in the late 1970s when Japanese companies began to enter the world market with well-designed high-quality products. Both countries' industries reached the market at the same time with the 64K product. New generations reached the market about every two and a half years.

Most U.S. merchant market semiconductor firms chose to concentrate their attention on one product generation at a time -- either designing the next product or fixing problems with the last one. Their speed in developing new product generations was as fast as any. But the need for haste forced many technical shortcuts, which were reflected in customer applications problems, making necessary a series of redesign efforts that dissipated initial product momentum.

The Japanese firms that now lead in this business followed a different strategy. At the time the 64K DRAM was introduced, they also had simultaneous efforts under way with two or three additional generations of product. The 256K DRAM was in advanced design, and the 1 megabit version was actively being researched. Very likely, a group was off thinking about what had to happen to make the 4 megabit product a reality as well. Products, when introduced to the market, were second or third generation designs, and thoroughly debugged.

Thus while U.S. companies turned their project teams from one generation to the next, they confronted a continuing series of well-designed competing new products in rapid succession. Japanese management drove DRAM development with the long haul in mind, and with commitment to development in depth.

Continuous improvement of existing products and processes is where U.S. companies can improve most. The sense of restless disquietude that prompts the management and work force of an entire company continuously to seek better ways requires an attention to detail and a persistence that do not seem to come easily to Americans. Even "cash cow" businesses require continuous investment to keep them current and competitive -- a fact neglected by many U.S. firms over the past several decades.

The risk in product- and process-improvement driven commercialization is in torpor. The failure to keep making improvements and to keep aware of progress in competing products ensures eventual problems in currently successful businesses. The "you can have it any color as long as it's black" mentality displays a rigidity of thought that provides entry opportunities for others.

There are many U.S.-based firms that have recognized the need for continuous updating of their products and process. Boeing's commercial aircraft technology has undergone almost continuous change as it has sought to incorporate the latest innovations into production airframes. Bill Boeing's dictum to "Let no advance in flying pass us by" has been accepted as a basic philosophy of this successful company's business.

The fourth commercialization type is similar to product and process improvement -- this is the <u>end game</u>. The process and product improvement philosophy that holds throughout the growth phase of a product line's life must continue into maturity. But the end game, our term for maturity in the cycle of product family life, has its own set of difficult challenges. Am I betting my company on a product line that will persist through market saturation and slower growth or will my product line be supplanted by another, superior technology? Do I have the resources and ability to continue to improve and maintain the product and its production technology and the dedication to hang on to the business while my competitors fall by the wayside during a period of low margins and slow growth? The end game challenge is to avoid losing the drive to continue improving while others are treating the business as a "cash cow."

Each type of commercialization -- technology-driven, market-driven, product- and process-improvement driven, and end game -- is a different kind of problem. Each requires its own management approach. Successful commercialization management is the process of balancing each of these efforts to meet the future business needs of the company -- a process that is both intellectual and

intuitive. The intellectual, or scientific part of management, consists, in part, of the use of analytical tools to understand how the effort is progressing -- to focus on the real processes at work in the midst of an inherently disorderly progression of ideas into products.

Management Tools

Traditionally, the primary management measures of the commercialization process are financial. Financial success (and demonstrating its likelihood at the outset) is crucial to commercial technological innovation. In the language of financial analysis, the value of current and future returns must exceed the investment. The logic is inexorable and sound. The problem arises in making the simple and tight logic of financial analysis work for decision making about technological issues in real companies, about matters of great uncertainty using information provided by less than neutral parties to the decision. Without other indicators of the promise and progress of commercialization efforts, financial techniques, with their apparent precision fill the void to dominate decisionmaking.

Consider, for example, a decision to proceed with development of a technologically new product for an undeveloped market. If one assumes absolute technological certainty, the calculation of return on investment for the development expense still requires estimates of:

- The cost of development of a prototype;
- The cost of manufacturing a product for which a prototype does not yet exist; and
- The market for, and likely sales of, a product that does not yet exist over the next several years (remembering that the product must be priced at a sufficient margin above a manufacturing cost that is not yet known).

Given that few technological developments proceed without many trial-and-error iterations, any decision maker will recognize the biases and negotiating positions that those who provide information are likely to bring to the table. Technological champions may underestimate development costs out of enthusiasm. The production staff may "pad" the estimates of production costs to give themselves some slack in scaleup. The marketing staff, really out on a limb measuring markets that do not exist, may bring any number of biases -- underestimation if they see their role as breaks on the technological champions or overestimation if they themselves have become champions of the product.

There is yet another set of constraints on the usefulness of financial analysis: business strategy. What is the value of this product as part of the company's portfolio? Does the company need to offer this service to keep competitors out of the company's primary market? Will the company-wide learning-by-doing that comes from a new product in this area of technology be of long-term value even if the product loses money? What is the strategic cost of not proceeding with this development?

Underlying these uncertain and often fuzzy judgments that must be translated into numbers for financial analysis are often fundamental questions about the technology and the technological capability of the company. Will the technology work? When somebody flips the switch, will the product grind, whir, and whiz in ways that meet consumer demand? And, can the people in the company pull it off faster or as fast as the competition. Given the uncertainty of the whole process, it is a wonder that any manager ever considers financial analysis of corporate technological matters -- but decision makers do look at financial calculations, probably because there is no other tool so pervasive or so easily understood. Regrettably, this breeds reliance on financial indicators as a substitute for a real understanding of the business -- financial measurements such as discounted cash flow and the profit and loss statement become an end in themselves rather than the short-term indicators of prospects or performance that they really are.

An important aspect of the NAE study, therefore, has been the search for useful tools to aid the management process. The committee has assembled a small catalog of commercialization indicators and techniques that help the leader in assembling business information in a way to make sense out of the chaos that pervades the commercialization activity. One warning -- standard analytical tools are just the beginning of the search for appropriate figures of merit for commercialization activity. Each business has its own set of constraints and success factors, so managers have to use the same kind of intuition and cunning used by skilled designers or problem solvers. The standard tools can only be thought-starters for inquisitive leaders.

Besides traditional financial tools that managers use to measure and plan the health of the business, methods such as technology road maps, learning curves, time-to-break even analysis, and logistic curve considerations can prompt action by leaders before chronic problems become acute. Many of these tools are not new but a more widespread understanding and use of them would be productive in a variety of industries. These tools are, in their very nature, more sensitive to the characteristics of the technological challenge than traditional financial analysis.

For technology-driven instances, the tools of value -- vaguely defined though they may be -- are those that allow a project team to develop the ability to look past current consumers to the market that will exist. In new product or service developments, an internally generated vision of the market success factors must be developed and refined by exposure to critics and customers.

New technologies characteristically must pass several critical decision points in the life of the development. At each such point, the investment commitment rises -- typically by an order of magnitude. Descriptions of decision points exist and are useful particularly to managers engaged in technology-driven commercialization.

In market-driven commercialization -- moving developed or developing technologies into new markets -- the approaches are again different. Most applications can be satisfied with a variety of technological approaches. Sometimes the application of an existing technology to a new market is dramatic, for example, technology-driven creation of a totally new product or service drawing mostly on existing knowledge. In other cases, efforts to move existing products and services lines into new markets are more incremental, and the technological challenge is in packaging and applying an existing technology so that it matches the particular characteristics of the market sought. Useful tools for market-driven situations are those that help in characterizing market needs and evaluating technological alternatives.

In product- and process-improvement commercialization -- continuous improvement in existing products and processes -- analytical tools are much more developed. Experience curves, benchmarking, product life cycle analysis, and product-age portfolio approaches are all part of set of tools demonstrated in a growing literature on manufacturing and technology management.

As mentioned earlier, any catalog of commercialization assessment tools can only go so far. Businesses differ in their fundamentals -- what works well for one firm may not work in another because the constraints may differ.

Organization

Just as with analytical tools, the best commercialization organization depends on the nature of the commercialization activity at hand. There is no time to go into all the organizational issues attending each commercialization type. However, it is worth making a couple of basic observations.

The "linear" or "waterfall" organization concept has been traditional in large U.S. firms since the rise of the industrial

research laboratory in the early twentieth century. By its very nature, linear compartmentalization emphasizes a sequential approach to commercialization. Technology transfer between organizational elements is a major weakness -- it takes time, and as with a bucket brigade, all is lost if the bucket is dropped somewhere along the line. Yet the linear choice does have merit in the case of technology-driven commercialization. In this case, a fundamental concept often requires a host of supporting innovations to bring an idea to market as a product or process, and time is available for intellectual gestation.

The fundamental alternative to the ladder organization is the product-realization model, or project-centered organization, where a project team follows the commercialization effort from outset to the market. The composition of such teams may change with time, but since a single group pursues a consistent set of objectives, there are few, if any, internal technology transfers, and delay and risk of transfer are lessened. While details differ, project structures are a good choice for new market-driven, product- and process-improvement driven, and end game commercialization efforts.

In spite of its inherent advantages, it is still possible to make project organization perform inefficiently if project goals are moving targets. If, as a project progresses, new or changed specifications are periodically added to the purpose and design of the product, the group effort may wander from one project review to the next and fail to converge on a desired result. This effect, termed "feature creep" by some insightful people at Hewlett-Packard, can effectively delay conclusion of a commercialization effort. Management must have the discipline to see a project through to conclusion unless major shifts in market or technology occur, in which case the effort should often be restarted.

This presentation has covered some of the findings of the Profiting from Innovation study. These observations, and others not addressed here, place emphasis on the importance of the leadership of a company understanding the nature of the business at hand. Each of the commercialization types described is unique and requires management techniques tailored to its special needs. If U.S. companies are to make the best use of their innovative capabilities, they must begin to manage the balance of efforts more skillfully. Finally, there is no substitute for the direct involvement of company leaders in the commercialization process to understand the true nature of the activities under way.

Thank you very much.

Mr. ROEMER. Thank you, Dr. Guile.

Dr. Boulton.

Dr. BOULTON. I think we all understand the problems that we are facing, and my prepared statement includes a lot of examples that we are all aware of, so I won't cover that. Let me summarize some of the key points of my testimony.

First, the U.S. has been extremely slow to respond. We are sitting here in 1991 talking about issues that were addressed in 1967. I was in Japan in 1972 working with an American corporation, a joint venture over there, and we were facing, and I remember Congress addressing, these issues back then, so, you know, it's deja vu all over again. You know, we are back here talking about things that we should have addressed or should have done something about a long time ago.

The reality is that I think American companies have believed that we are superior in everything and therefore we don't have to respond to foreign competition, and, in contrast, we have had particularly the Japanese government make very long-term commitments to technology. You know, in 1952 when we forced AT&T to give up the transistor technology to whoever wanted it, the Japanese government said, "We will be a major leader in this technology," and then, of course, TI came out with the semiconductor, the IC chip, and sort of blew them out of the water, and fortunately for Japan TI wanted to go to Japan, and the condition to go to Japan was that they give up the technology and that they license its technology to Japanese companies. The same thing happened with IBM, you know. IBM wanted to go to Japan, and fortunately for the Japanese the only way to get in was to give up their technology.

The Japanese have had a technology commitment for a long time, and the markets that we lost are not markets that we lost yesterday. These are markets that have been worked on for decades, and we have been very slow to respond.

When we finally recognized that the Japanese were a threat, the first response we have always made is political. We come running to Government and say, "It's unfair competition, and you guys need to do something about it, because obviously it can't be us, we're too good." Eventually, after the Japanese take 40 percent of our market, then we come back and say, "Oops, it's too hard to compete in these industries, so let's go find some place easier to compete," and we start to withdraw from the core of our businesses, and, as a result of that, we become weaker and weaker in terms of the competition. The final response is that we say, "Well, gee whiz, our business is based on this particular industry, and we have to go back and reinvest." The problem is that when we go back to reinvest we are now at a competitive disadvantage and we are trying to rebuild an industry from a position of weakness rather than to maintain a strength that we once had.

We did a study in 1988, had a dissertation finished, that looked at our response, and we found that this response is the same in every industry that we are losing. It is a consistent response, it has not changed, it is a behavioral pattern that seems to be inbred upon our society, and we have yet—I think the SII is the current example of our political response to problems of competition.

Now let me go on to address a little bit about the Japanese long-term commitment to advanced technology and commercialization, and I'm going to give you the example of robotics. Japan never saw a robot until 1968, and we took our robots to Japan to display, and they saw the vision of future impact of robots on industry, and they grabbed hold of that vision, and they licensed our technology and started producing robots very shortly after 1968. By 1973, they were producing better robots that lasted longer than what we had in this country. By 1984, they had 64 percent of all installed industrial robots in the world were installed in Japan, only 15 percent in the United States. So it is a question of having a vision and then having the Government support those activities.

Now the nature of support particularly and the kind of incentives they give is, as soon as they identify a potential industry or potential technologies, to set up an association that has the primary responsibility for coordinating technology and standardization and development of that particular technology or industry. Now they do this before the industry is actually developed but looking in terms of a potential industry, and MITI has done this, and, in addition, they passed, for example—in 1971 they set up their Japan Industrial Robot Association. The same year, they passed the Machine and Electronics Industry laws that were used to basically provide two incentives on two parts: one, for people to develop those high-tech machines to give them special investment incentives, and, secondly, they set up incentives, or tax incentives, for people to buy the machines so that they would encourage the market as well as encourage the development of the technology. Both of those are simultaneous problems that have to occur if you are going to get into the market quickly.

At the same time, they found that companies—that the new robots, new technology, were high cost, so they set up their Japan Industrial Robot Leasing Corporation in order to help finance the development of the marketplace and encourage people to take that technology.

Now I point this out because this has, again, been systemic in virtually every technology area the Japanese have gotten into. They have a strategy that is understood; they know how to take technology to the market; they know how to support it; and, this is government-based support for the development of specific areas that they have targeted.

Now let me come back to the United States for a minute and talk about a fundamental problem that a number of you already mentioned, and that is that we have a problem in terms of how we think about science and technology. We believe in science. If you look at the development of education in the United States and Japan, we both have our derivation from the German system. The German system really has two directions; one direction goes into theory and science; the other direction goes into application.

What has happened is that we have taken the high road in this country, and, as a result, we have focused on science and theoretical education. The Japanese took the low road and basically are applied. You will never see anybody in this country applaud a Japanese university. You know, we talk about the lack of Nobel laureates in Japan, but they beat us in every market that we enter. The

reason is that they are very applied oriented, we are very theoretic oriented, and that has a lot of significant implications.

Particularly in our universities, we basically use the scientific method of evaluation of our people. "Scientific method" means the only way you can tell if a new science is good or bad is whether or not it is repeatable, and the only way it is repeatable is if you take some of these methods, you try them out again, and you get the same result. As a result, what we use is a peer evaluation process, because only other scientists with those methods can evaluate the methodology and the result of that methodology. That has nothing to do with application.

Any applied discipline on a university campus continues to struggle for survival because we basically use the scientific method to determine whether or not they are doing a good job, so our areas like music and art, which are applied disciplines, are always on the bottom rung of status in any institution that we are a part of. The business schools constantly struggle, and the only way that we can maintain status is to basically try to use scientific method in our own disciplines, and as a result we get further and further away from the markets that we are supposed to be addressing, the applied areas.

Now, in contrast, the Japanese have been particularly engineering oriented, and we know that they are good at engineering because they basically have an applied system of education. So, as an example, one company I was consulting with has moved its engineering applications to Japan because they found, by coincidence, that they could take new technology to Japan and develop it in half the time using graduates—engineering graduates with undergraduate degrees in engineering when it would take three times as long for Ph.D.'s in the United States to develop the same technology, because we are not application-oriented, we give no regard or respect for applied disciplines in this country. The only place you can get status if you are an engineer in this country is if you go into Star Wars and defense technology that is state of the art, out there on the outer limits. So we have a problem in terms of incentives and a problem in terms of directing people into these particular areas.

Now, at the same time, we have no focus on process engineering, or process development, or process innovation. We basically believe in the dream of the hereafter, which is an example here of the ear plugs. We take a technology, and we want a product, and a breakthrough product, that gives us a great future. What we don't do is, we don't develop that product into lower cost, higher quality applications, and that is all process engineering, because that is the application and that is an area that we don't respect and we don't give status to, so our best and our brightest are not going to go into those areas.

Since Japan has never had science as an area discipline, the Japanese obviously give very high status to their engineers who are very applied, and, as a result, we see a tremendous difference in our capability in process engineering.

Now, finally, there are three areas particularly that are important in terms of thinking about commercialization of technology, and they are basically what I call risk factors. There is a technical

risk factor, which means that even after we create this great new technology, there is no guarantee that it is going to work when we apply it in the marketplace, and companies are very averse to investing an enormous amount of money in developing those technologies and still having them fail. Until we do something to address how we do that, in fact, about 90 percent of the investment goes into development work for products to get them into the market, so if we are investing that kind of money in development and we have enormous risk, people are going to shy away from it.

Secondly, of course, we have the market risk, and that is, if you get into advanced technology, you have to make sure that somebody is going to buy it after you put it out there, and we need basically incentive kinds of activities that cause markets to develop, and, finally, there is an area that I think is more important, and it is one that is addressed. It is a short-term issue which I call performance risk.

When you go through the commercialization process, there's two things that happen: Your expenses go up, because you have to invest more and more in R&D, and—your expenses for R&D go up; secondly, you have to invest more in capital in order to produce the product and get it to market, and you have no income. If you are using a measure like return on investment as a determination of your performance, and that's how you keep your job and that's how we keep the stock price of our corporations up, then inherently, by going into developing these technologies, two things are going to happen: As expenses go up and investments go up, ROI will inherently go down in virtually every case.

So what we have is a disincentive system for rapid commercialization just because of the kind of measures we are using today. So what we have to look at is ways that we can reduce the risk of performance for corporations if we want to facilitate and encourage them to get involved in this process.

Now the Japanese use all kinds of systems, and it's in my prepared testimony. I specifically identified a number of areas to give you examples, but let me just say that one of the areas that they have been involved in is in small business and medium business modernization activities. They have actually set up a whole system whereby they not just—they provide technical support, they provide subsidies to get new technology into small business. They actually go out and help small business develop strategies for their industries in order for them to be commercially successful.

One of the things that I have been trying to do is to investigate the areas of bottlenecks in our system. Let me just come back home now. I have sent out, trying to get funding for doing research and identifying problems of commercialization in this country for five years now, and the common response I have gotten from virtually every agency that uses funding for technology in this country is that their mission does not encompass how to do it effectively, and, as a result, I have been able to get no support from any Government agency to do research on how to facilitate the process of getting those technologies into the marketplace.

We need to define what the role of Government should be in this whole process, and we have to begin to look at it as a process from beginning to end and say, at a macro level, where should the Gov-

ernment be involved? what are the systems, particularly in the nondefense area? because we are doing all right in defense, it is in the non-defense areas where we basically have an ideological problem in this country, and the question is, what should be the role of Government?

Traditionally, the role of Government really is twofold. One is that the role of Government in this country is to be the world policeman. We have the biggest defense budget, we have the biggest research, and all of the development expense in Government goes into defense development costs; over 90 percent of our money in the defense area is going for development. In contrast, in the private side, virtually 90—well, less than 30 percent of our money is going into development; the rest of it is going into science and into applied activities.

We don't have any methodology that tracks the technologies that are available in this country. If you decide that you have a technical problem, there is no easy way for you to find out where a potential solution is. We need to build some data bases that capture what is available out there so that people can get access to technology that will facilitate the process. We don't have any organizations set up that actually do assessments of technology to determine whether or not there is a future for it.

I have suggested, for example, that under our SBA program we have SBDC's at every university. Why don't we create an SBDC with a mission of taking new technologies and doing the initial market surveys to see if there is an application?

We need to begin to develop some kind of a support for new prototype development. The big cost—you know, to reduce technology risk, we have to apply that technology into an application and see if it works. Once you get the technology to work, what you have done is, you have reduced the technological risk to corporations. In Japan, for example, when they did their project on flexible manufacturing and laser welding, the bottom line was that there were two companies in Japan before they started the project that had laser welding technology. One year after the project was finished, there were 12 products on the market on laser welding technology. The technology was proved, and everybody jumped into the market quickly.

Finally, we need to stimulate demand. We need incentives in particular targeted new technology areas to encourage business to take a hold and build the demand so that we can get companies interested and active in doing that.

So I'll summarize by simply saying that we need to shift our whole focus and begin to look at the system, identify the bottlenecks in the system that are discouraging commercialization, and begin to either replace—remove the bottlenecks or put in mechanisms that will facilitate the process.

Thank you.

[The prepared statement of Dr. Boulton follows:]

Acceleration of U.S. Technology Utilization and Commercialization

Testimony of
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Before the
Subcommittee on Technology and Competitiveness
Committee on Science, Space, and Technology's
U.S. House of Representatives
Washington, D.C. 20515
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Room 2325 Rayburn House Office Building
Washington D.C.

I want to thank you for inviting me to come before you today. My remarks will be directed at a number of areas that I have found to be critical to competitive new technology commercialization activites. I have taught graduate courses in the business school in the management of technology and innovation for over five years. I have been carrying out research in this area for over a decade. My remarks are most often directed at Japan for comparison purposes. I have spent over five years in Japan as a student, practitioner, and academic researcher. I spent six months in 1986 researching Japan's technological developments in the robotics and factory automation industry. Next month I will return to Japan under a grant from Japan's Ministry of Finance to look at how national priorities and funding decisions are made to support technology development.

My comments today will address concerns about the U.S. lack of competitive responses to Japan, and will focus on problems relating to our overemphasis on science, our misdirection of engineering, our lack of risk reduction activities for industry, and our need for government to take a more aggressive role in the management of innovation in the United States. Let me begin.

I. Foreign Competition Has Been Steadily Increasing.

Technological competitiveness is a growing concern for the U.S. The United States' position as post-war leader in manufacturing and advanced technologies has come into question as countries in Europe and Asia improve their competitive capabilities. The United States' loss of market share to foreign competition continues. The Department of Commerce's Council on Competitiveness points out the decline of U.S. world market shares in a number of technology based industries between 1980 and 1987. These declines included:

	(Percent of World Market Share)	
	1980	1988
Steel	14.2	11.6
Automobiles	20.6	23.2
Machine tools	18.2	6.7
Fiber optics	73.0	41.9
Semiconductors	60.0	36.0
DRAMS	55.6	20.0
Supercomputers	100.0	76.0

Much of our concern is that the U.S. has lost its lead in these major areas of technology. The

1988 White Paper of Japan's Ministry of International Trade and Industry assessed U.S. technology strength as being behind only in areas of semiconductor memory chips, VCRs, photovoltaics, and fince ceramics. In all other areas of technology, the U.S. was equal or ahead of Japan. The future problem relates to the U.S.'s technology development capability. MITI assessed the U.S. development capability to be equal or ahead of Japan only in data bases, computers, communications satellites, aircraft engines, skyscrapers, and advanced composite materials. During the 1980s, Japan surpassed the U.S. development capabilities is such areas as semiconductor memory devices, PBXs, micro-processors, laser printers, copy machines, CAD/CAM, and photovoltaics.

Japan's advanced development capability is directly related to speed of advanced technology commercialization efforts. A company that can bring out new products three times faster than its competitors enjoys a huge competitive advantage. Japanese manufacturers are doing just that to U.S. competition. For example:

- ☞ In projection television, Japanese producers can develop a new television in one-third the time required by US manufacturers.

- ☞ In custom plastic injection molds, Japanese companies can develop the molds in one-third the time of US competitors and at one-third the cost.

- ☞ In automobiles, Japanese companies can develop new products in half the time -- and with half as many people -- as its United States competition.

While investments in product design and flexible manufacturing account for much of Japan's ability to introduce new technology and products rapidly into the market, wide-spread government programs have been significant in encouraging and supporting such investments.

2. The U.S. Has Been Slow To Respond To Foreign Competition.

The United States is the easiest place in the world to do business. Its markets are vast and provide for easy geographic segmentation. Competition has been relatively benign. As a result, U.S. companies have been ill prepared to respond to the onslaught of aggressive foreign competition. They most often respond by asking for government help. Government has not really believed that it should be responsible for industrial problems and is not organized to respond to international competition. Instead, the U.S. has relied on antitrust activities to regulate competition. There is no equivalent in the United States to Japan's Ministry of

International Trade and Industry. It would take a ideological shift to make such a competitive move.

Growing world competition continues to be met by the slow and weak responses of U.S. firms. Over the past several decades, U.S. firms have slipped from the role of world leader towards becoming a world follower. Rather than improving competitive performance, U.S. firms sought political help. After political negotiation failed to slow foreign competition, U.S. firms often retreated into less competitive segments of the business. Unfortunately, the retreat from competition often left only smaller markets that were also vulnerable to foreign competition. In the end, U.S. firms have had to either exit their business or re-commit themselves to major investments in the business -- typically from a weakened competitive position. This response pattern has yet to change.

Unfortunately, research shows that the U.S. competitive response has been meager and slow. For example, in semiconductor competition, their slow and weak response paralleled that of the steel and automobile industries. Research completed in 1988 entitled, "Strategies for Business Facing Strong International Competition: An analysis of the American response to the Japanese challenge," found the following U.S. response pattern:

✔**Japan' MITI Made Long-term Commitments**: The success of Japanese firms in the semiconductor industry was heavily dependant on their government's support. As early as 1952, Japan's Ministry of International Trade and Industry's (MITI) Electrotechnical Laboratory had become committed to transistor technology and its applications in electronics and computers. Early efforts were overshadowed by Texas Instrument's (TI) invention of integrated circuits in 1958. When TI wanted to enter the Japanese market in 1962, MITI insisted that TI license its IC technology to Japanese firms. By 1969, MITI had approved license agreements from National Semiconductor, Motorola, and TI for NEC, Mitsubishi, Toshiba, Fujitsu, Hitachi, Sony, Oki, Sharp, and Casio. All of these firms had begun semiconductor production in Japan. In addition, MITI had limited Texas Instruments' entry into Japan to a joint venture with Sony Corporation and a maximum market share in Japan of only 10 percent. As a result, TI was restricted from taking advantage of its leadership position in the Japanese semiconductor market.

✔**Japan Targeted The U.S. For Its Expansion**: By 1973, the Japanese had entered the commodity segment of the IC market in the U.S. By 1979, they expanded their market by aggressively selling dynamic RAM memory chips into the U.S. Japan's entry into

semiconductors was never considered a serious threat until 1979, after Japan had achieved a 43% share of the commodity chip segment and had entered the 64K DRAM chip market.

✔**The U.S. Did Not Respond**: U.S. confidence in its technology and manufacturing skills had caused perceptual lags in evaluating the seriousness of Japanese competition. Few U.S. managers admitted to the competitive threat. By the time the Japanese dominated the market, U.S. competitors were in trouble. U.S. firms with high technical and managerial skills had dominated the merchant segment of the semiconductor market. They lacked the resources and skills needed to defend their positions in the high-volume and low-performance market segment being attacked by Japanese competitors. Large Japanese firms used low cost production expertise and a willingness to sacrifice short-term profits in their attack.

✔**U.S. Firms Looked For Government Help**: Large U.S. firms, such as Motorola and National, responded by lobbying the U.S. government for protection against Japanese competition as their market position and performance declined. The only competitive response of U.S. companies was to withdraw from competitive segments of the market, or to develop joint ventures with Japanese competitors. U.S. firms moved into customized chip segments and more advanced systems markets where they felt they still had an advantage.

✔**U.S. Strategic Responses Were Defensive**: U.S. technology driven firms (Intel) began to improve their own manufacturing and marketing skills in an effort to respond to the Japanese challenge. Marketing driven firms (AMD) began to improve their technical and manufacturing skills. Manufacturing driven firms (National Semiconductor) began to improve their marketing skills. However, the most important shift in U.S. competitive strategies was that U.S. firms began to collaborate with technological and financial ties in such consortiums as MCC and Sematec (a cooperative program between DARPA and the industry). While U.S. firms began to respond, by 1990, the Japanese had dominated the dynamic RAM segment of the semiconductor market with over 90% of the market.

As U.S. industry and government continue their mediocre competitive response to global competition, continuing decay of present and future U.S. markets positions can be expected.

3. MITI Continues To Support Advanced Technology and Commercialization.

Quality, cost and time in getting new products to the market are the basic components of value creating strategies in today's markets. Advanced manufacturing and information technologies support such "value creation" strategies. The U.S. move away from manufacturing and related value creation strategies will continue to limit improvements in the standard of living which derive from improved productivity. The shift into service industries, the electronic sweatshops of the future, will create little sustainable value for tomorrows' society.

In 1986, I conducted research in Japan to determine the country's capabilities in advanced manufacturing technologies. I knew that Japan had a competitive advantage in manufacturing, but I wanted to know just how significant that advantage had become. I visited the companies that dominated Japan's robotics and factory automation industry. Those companies who were involved in selling today's advanced manufacturing equipment and developing next generation equipment. What I found was shocking -- Japan was perhaps ten years ahead of the U.S. in applying advanced manufacturing and related technology. Japan now holds nearly one-third of the world market share in advanced machine tools and two thirds of the robotics market. By 1984, Japan had become the world leader in machine tools sales with $4.4 billion in sales compared to $2.4 billion for the U.S. In that same year, Japan produced nearly 41,000 industrial robots, with nearly 65 percent of all industrial robots in the world being installed in Japan compared to only 15 percent in the U.S.

Investment in the commercialization of industrial robots was a deliberate strategy to gain flexibility in manufacturing. Consider the support its development received:

✔**Government Must Have A Vision Of The Future**. The Japan External Trade Organization (JETRO), an arm of the Ministry of International Trade and Industry (MITI) to seek out advanced technologies, held an exhibition of robots in Japan in 1968. While Japanese firm's had become the leaders in mass production technology, they saw the potential of robotic applications for increasing flexibility in manufacturing and for replacing skilled workers that were in short supply. To investigate the potential of these robots, Japanese companies licensed the rights to produce Unimation robots in Japan in 1968 and began experimenting with robots on the production lines. The U.S. firm Unimation had developed the first U.S. robots, but were unable to find a market. During the early 1970s, Japanese manufacturers, such as Honda, experimented with robot application on their production lines.

45-435 - 91 - 3

✔**Government Must Provide Support and Incentives**: MITI established the Japan Industrial Robot Association in 1971 to coordinate research efforts, standardize operating systems, and disseminate information between potential users and producers for robots. At the same time, MITI replaced its Machine and Electronics Industry Laws with the Law on Temporary Measures for the Promotion of Specified Electronics Industries and Specified Machinery Industries. This new law gave special credit for development of advanced manufacturing equipment and provided accelerated depreciation for companies purchasing such equipment. Low interest loans and leases were provided to encourage the purchase of advanced manufacturing technology. Such incentives encouraged Japanese companies to invest 25% of GNP in new plant and equipment, as compared to only 12% for the United States. Health and safety work laws were strengthed to encourage companies to remove workers from dangerous jobs.

Rapid commercialization of advanced manufacturing technology required more than a desire to get new computer-driven machine tools and robots to the market quickly. It required a system that supported rapid commercialization through incentives for both the producers and users of such technologies and products. In new industries, demand must be stimulated to encourage firms to take the risks of early market entry. In Japan, for example, the government encouraged purchases of robots, which were very high cost, by enforcing government health and safety laws. At the same time, it set up the Japan Robot Leasing Corporation to help finance such investments for small and medium sized businesses. Therefore, firms had incentives to buy robots that might not otherwise be cost justified. This is similar to the approach used in U.S. defense programs.

4. Scientific Leadership Does Not Guaranteed Successful Commercialization.

What role does scientific leadership have in rapid commercialization? There is long standing debate as to what country is the leader in science. I don't really see the need for debate. The United States invests over $70 billion per year in research and development and is still the overall leader in science. We are still granted nearly two and a half times the number of Japanese new patents (53% compared to 21% in 1989). We have the majority of scientists in and world (75 per 10,000 labor force compared to 70 in Japan) and educate the majority of scientists and engineers (40% more than in Japan). The problem is that being the world leader in science and engineering does not guarantee long term success in the marketplace. All of those

industries in which we have lost leadership had been started from U.S. technological innovation. It was not the science that determined long term succes, it was more often design and manufacturing capabilities.

The recent results of the war with Iraq suggested that the U.S. is a leader in the defense industry. Both the Soviet Union and China have admitted to our leadership. So why have we been so successful? I would argue that it is due to the heavy investment in development expenditures in defense. In relative terms, according to the National Science Foundation, nearly 90 percent of R&D expenditures in defense are for development. Only 10 percent of our expenditures are for basic and applied research activities. In non-defense areas, the Federal government spends only under 30 percent of R&D monies on development. Over 40 percent of non-defense funds are spent on basic research and nearly 30 percent on applies research. It is assumed that the private sector will do the development work in non-defense areas -- an assumption that has not proven correct.

Scientific knowledge in non-defense areas is readily available to anyone around the globe. U.S. science and technology is no longer the sole property of U.S. companies. Science is a "social" good available to anyone who seeks it out. For example, most Japanese companies have students attending U.S. universities to track the latest developments in science and technology. New knowledge is quickly transferred back to Japan or elsewhere since over 50% of U.S. graduate students are from foreign countries. MITI has also supported the development of data bases for technologies to ensure rapid access to the latest scientific publications. For example, when high temperature superconductivity was announced, it took a team of Japanese scientists and engineers less than ten days to replicate the findings.

In fact, science cannot be well protected. The system by which scientific knowledge is created requires that scientists have their results and methodologies evaluated and reproduced by their peers to ensure correctness and repeatability. "Good science" uses methods that can be replicated to produce the same results. As a result, scientific works are published for all to see and challenge. This open system of review is not conducive to patent protection since most information falls into the public domain and decreases the potential for protection of new knowledge. In fact, until recently, the NIH and other government funding agencies required that government funded research be placed in the public domain. Changes in the policy were intended to encourage scientists to commercialize their own discoveries by patenting their results. The patenting process requires scientific confidentiality until the patent is submitted to keep it out of the public domain. This process will, in fact, delay public disclosures. Since there

are few systems in place to facilitate commercialization, it may even be more likely to delay overall commercialization of new knowledge.

5. Engineering Leadership Is Critical To Commercialization.

✔**We Don't Appreciate Applied Disciplines Outside Of Defense.** The U.S. and Japan both derive their educational systems from the Germans. The German two-tier system separates theoretical education from applied education. The United States' universities have adopted the theoretical aspects of German higher education, while Japanese universities have adopted applied education. Theoretical education is more appropriate for the study of science than for the applied requirements of commercialization. With their applied focus, Japanese universities have gained a competitive advantage in carrying out the applied engineering requirements of commercialization activities. For example, a major U.S. company recently found that Japanese engineers with undergraduate educations could complete product development requirements in under half the time it would take for their U.S. laboratory's using Ph.D.s to complete the same developments.

U.S. universities use peer evaluations as the basis for promotion an tenure of its faculty. While peer evaluations may be appropriate for fields of science, they are less meaningful for applied disciplines that direct their activities toward users of their knowledge, not towards their scientific peers. As a result, applied activities of universities are generally considered second class and have difficulty obtaining promotion and tenure. Since technology commercialization is an applied activity, it is not considered appropriate behavior for theoreticians. In fact, academics argue that application of their science inherently creates a "conflict of interest."

"Peer evaluation" measurement systems force all university disciplines to look "scientific" in their research and publications if they are to obtain promotion and tenure. For example, schools of business have become mostly irrelevant to the business community as their faculty push to publish in "peer reviewed" journals that use "scientific looking" methodologies. Schools of art and music are most seriously damaged by this ideology based on the "scientific methods." Engineering schools have also adopted the "scientific methods," making them less useful in solving problems of application and commercialization. Disciplines not meeting the requirements of the "scientific method's" ideology have become lower status fields of study.

Since Japan has never had schools of science, it lacks the pressure to meet the rigorous demands of "scientific method". As a result, while Japanese engineers are extremely applied

they also have a very high status in Japan. Over 26% of university degrees given in Japan are in engineering degrees as compared to under 20% of U.S. degrees in both science and engineering degrees. This difference gives Japan a competitive advantage in engineering. Since these engineers are also employed in primarily non-defense industries, it should not be surprising that Japanese firms are more competitive in new technology commercialization than U.S. non-defense firms.

✔**We Don't Encourage Process Innovations**. Since the U.S. values creativity that leads to product innovations, U.S. engineers prefer to participate in "star wars" and "high technology defense" programs, not in improving the processes by which commercial products are made. Since neither NASA, DOD, or DOE are "cost driven" organizations -- their advanced technology projects systematically run costs up far beyond anyone's wildest expectations -- they have little concern for process innovations. In contrast, Japanese firms seek to maximize quality and costs in their commercialization efforts.

To reduce product costs, products are re-designed and engineered for efficient manufacturing as new manufacturing processes are developed at the same time to reduce costs. For example, Matsushita dominates the VCR market after dramatically reducing the labor content in VCR assembly. Instead of using shims to adjust the video heads, Matsushita changed its process to grind the video heads after installation, thereby eliminating the need for adjustments to pre-ground heads. Matsushita's process innovation lowered costs significantly and allowed the price of VCRs to drop significantly, eliminating higher cost competition.

The results of Japan's process innovations, driven by Kaizen or "continuous improvements," are shown in productivity statistics. For example, the decade of the 1980s showed only a 12% improvement in U.S. productivity as compared to 33% for Japan. Such innovations, of course, have also required heavy investment for improved plant and equipment. With government investment incentives for advanced manufacturing technology, Japan has invested 25% of GNP for plant and equipment as compared to only 12% for the U.S.

High capital costs, averaging 11% for the U.S. as compared to 7% for Japan, also provides a dis-incentive to U.S. managers to invest in plant and equipment, the basis for improved productivity. Return on investments must exceed the cost of capital to justify such investments. The lower costs of capital in Japan makes it easier for them to justify such investments. With such high costs of capital, it is hard to generate adequate ROI for normal investments. Returns beyond five years into the future contribute little to present value of future

returns. Unfortunately, ROI measures do not consider the competitive dimensions of staying in business. By not making competitive investments in plant and equipment, U.S. companies will continue to be at a competitive disadvantage in the long run.

6. The U.S. Has Significant Barriers To Innovation and Commercialization.

In considering the life cycle of technology and its commercialization, we find that the majority of risks come during the product development stage. Of the total costs of new product introduction, as much as 90% of the cost comes during the development period, prior to product introduction. This demands advanced investment and expenses prior to revenue generation. The result of increased investment and expenses is that company financial performance generally declines.

✔**Technical Risks Must Be Reduced**. New science and technology is primarily developed in large scale research institution such as universities and government or corporate laboratories. This new knowledge may have a wide range of potential applications, but the cost of developing any product-market application can be substantial. First, R&D must be redirected to ensure that the science or technology will meet the basic requirements of the product-market application. Once the technology is worked out for the application, the actual product must be developed. The costs of research and development before actual product development is generally less than 10 percent of the total development costs. In fact, as one approaches market introduction, costs continue to increase at a geometric rate of increase. This adds significantly to both the expenses of doing business and the investment, i.e. investment increases and returns decrease. The net result is that ROI tends to go down when we decide to commercialize new products. That is a negative incentive for companies to innovate.

✔**Market Risks Must Be Reduced**. Product innovation relates primarily to the application of new science or technology to new products. The biotechnology area epitomizes the difficulties related to such advanced product innovations. It typically takes a decade to get a new product to market and then the price is so high that few can afford to buy it. New cardiovascular thrombolytic agents for dissolving blood clots cost $8,000 for the procedure, costing Medicare over $81 million in 1989. Magnetic resonance imaging (MRI) scanners cost about $1.5 million apiece, resulting in patient costs of $850 per procedure. Without third-party insurance willing to subsidize these enormous costs, there would be no such market in the U.S. In areas related to "star wars" and defense activities, the government pays high prices for development work needed for advanced systems. In the 1950s, it was defense related demand

that allowed U.S. companies to enter the semiconductor fields or develop high precision machine tools. Unfortunately, the durability and precision needed for such applications are not cost competitive for private industry applications.

✔**Performance Risks Must Be Reduced**. Developing new technologies for specific product-market application are high risk and costly for the average entrepreneur to finance. New science must be transformed into standardized technologies before new innovations can be produced. New high technology ventures must find financial support for development expenses that can take up to ten years before sales are generated. Private enterprise, which uses return on investment (ROI) as their measure of performance, cannot make such long term investments in product development without negatively affecting the firm's stock value or the individual's performance ratings. It is a easy to understand how the use of return on investment (ROI) can negatively affect commercialization activities. ROI Delines = (No $\frac{\text{Revenues - High Expenses}}{\text{Investments Increases}}$)

Instead, large firms and government leave it to entrepreneurs to bear the technological risks and prove the existence of a marketplace. Rather than risking low returns and high risks, large firms prefer to acquire an established enterprise and then invest the capital needed to grow the business. This strategy has resulted in less innovative U.S. companies that invest little in R&D.

Singapore currently offers to split the cost of R&D with companies that will move their operations to Singapore. It should not take too many years before Singapore become the center of research in Asia. As companies take advantage of these incentives, it is sure to have some impact on the level of research carried out in the U.S.

7. Japan Has Used Government Policies To Reduce Risks.

Japan's Ministries have traditionally been responsible for sponsoring and implementing legislation relating to their industries. Ministry proposals typically included:

1. special tax incentives,
2. tariff rates,
3. import policies,
4. investment policies,
5. patent and technology agreements,
6. joint ventures,
7. capacity limitations for industries, and
8. funding support from government financial institutions.

✔**Temporary Laws Are Used To Build And Revitalize Industries**. To overcome natural resistance to innovation, Japan passed its Small and Medium Enterprise Modernization Promotion Law in 1963. By 1980, 40 industries had been identified as needing structural improvements and to obtain loans and preferential tax treatments. The Small and Medium Enterprise Agency helped firms with industrial pollution and environmental problems, technical problems, and strategy determination. The law also focused attention on technological upgrading to develop new products, improve quality, or cut costs of production or energy. The Small Business Corporation also developed and disseminated prototypes of machinery urgently needed for modernization and labor saving in small firms, and coordinated research findings of public testing and research institutes. The Small Business Finance Corporation provided financial assistance for the commercialization of new technology. The Small Business Corporation also provided technical training and information to small business, and facilitated exchanges of technology between large enterprises and small business.

✔**Associations Are Used To Coordinate Industry Strategies**. Associations were established by MITI to proved the foundation for research in developing industries. As soon as a major technological problem was identified, usually relating to standardization, MITI would organize all of the concerned companies into a new association. The International Robotics and Factory Automation Center (IROFA), established in 1985, was funded by major users and manufacturers of factory automation products. IROFA was involved in research directed at developing an unmanned factory run by robot and factory automation systems. The initial projects were to determine the current level of knowledge by establishing a computer-aided high technology information system for robotics and FA technology, and to develop information exchanges, international conferences, and cooperative research programs that would help it achieve its objective. Member companies initially invested $1.5 million to start IROFA and committed $1 million per year for operating expenses. IROFA would be involved in all other government funded projects related to these areas.

8. Government Must See Its Role As Managing The Innovation Process.

The primary role of the U.S. government has been dominated by heavy investment in defense-related activities. The secondary role has been in social systems that include medicine and welfare. In fact, these roles of "international policeman" and "protector of last resort" have essentially left business to the private, once "free", enterprise system. The current arguments against government involvement in industrial policy are simply not realistic in today's competitive environment. In Europe, R&D support has targeted materials, semiconductor

production, computer and information technologies, and telecomunications through such organizations as RACE, BRITE, EUREKA, and ESPRIT.

✔**MITI Manages Japan's Innovation Process**. In Japan, for example, the Ministry of International Trade and Industry's (MITI) Agency for Industrial Science and Technology (AIST) has the primary mission of conducting research and development on industrial technology. AIST is the largest public research institutes in Japan, covering material science to biotechnology. Nine of its 16 laboratories, located in Tsukuba Science City, focused on comprehensive research targeted at specific technologies for use in industry. AIST's General Coordination Department includes planning for industrial technology policy, promotion of government-funded national projects, assists in private R&D activities, promotes international research cooperation, and facilitates regional technological developments. Its Standards Department is responsible for industrial standardization. AIST accounts for one forth of Japan's total governmental research personnel, and nearly 10 percent of Japan's R&D budget.

✔**MITI Targets Industry Problems**. AIST's four major national projects account for over 55% of its budget outlays. The R&D project for Basic Technology for the Next Generation, started in 1981, covers biotechnology, new materials, and new electronic devices. This program is aimed at providing the technical foundation for the creation of advanced industries for this decade. Two energy related programs are the Sunshine and Moonlight projects. The former aims at developing new energy technology; the latter, energy conservation technology. Finally, the Large-Scale Project, started in 1966, funds the application of new technology to new prototype in areas that need rapid development. These Large-Scale Projects are especially important in that they prove the application of new technology, thereby reducing the technical risks to industry. Once a prototype is developed using new technology, companies quickly develop their own products and take them quickly to market. For example, completion of the Flexible Manufacturing System with Laser Welding in 1985 found 12 new laser welding products on the market by 1986. There had only been two companies in Japan with laser welding technology when the project began in 1977.

The United States has no equivalent organization to support industry's competitive needs or subsidize the development of next generation technologies. The National Science Foundation initiates, evaluates and supports basic scientific research and educational programs. The National Research Council conducts policy and scientific studies at the requiest of the government. The Federal Technology Transfer Acts promotes the commercialization of Federal laboratory research. There has been an increased awareness and interest in patenting

technologies from within these labs. From the 780 Federal Laboratories, one might conservatively expect 25 patent applications per Lab per year. At a legal cost of $50,000 per patent for world-wide rights, this could easily cost the labs an additional $1,250,000 million per year in patent costs without any short term income to cover this cost. Nationally, this would cost the government nearly $1 billion just in legal fees resulting from the incentives related to the Technology Transfer Acts. To date, the GAO reports less than $10 million in licensing fees from current patents (compared to over $30 million in Japan).

9. We Need To Address Bottlenecks In The Technology Commercialization Process

I am currently working with the Oak Ridge Associated Universities to submit a major research grant application to investigate and present proposals on many of the issues addressed in the testimony. After considering the problems of technology commercialization in the U.S., we have identified several critical questions that need to be answered before improvements in U.S. commercialization are likely to occur. These questions relate to a variety of bottlenecks that have been identified in the U.S. innovation process that need to be overcome. We believe that we need to answer the following:

✔**We Need To Define Government's Role In The Innovation Process**. What roles will government play in managing each stage of the innovation process, from science and technology to product commercialization? What will be government's role in ensuring that we have effective education in science and technology as well as its applications?

✔**We Need To Build An Effective Innovation System For Non-defense Industries**. What are the barriers to technological innovation and commercialization in the U.S.? How can we remove these barriers? What mechanisms are missing in the innovation process?

✔**We Need Technology Data Bases**. How can we more effectively track our level of technological developments? How do we know when technologies are available for commercialization? What type of clearing house can be established? How do we identify organizations that have a need for such technology?

✔**We Need Technology Assessment Organizations**. How do we assess priorities and potential for new technologies? What institutions can facilitate technology screening and evaluate the potential applications and markets for new technologies?

✔**We Need Support For Early Development Of Prototypes**. How can we reduce technical risks? What programs are needed to fund early prototype developments for new technologies?

✔**We Need Incentives To Stimulate Demand In New Markets**. How do we encourage new product commercialization through market demands?

While there is no short term resolution to the problems of competitive commercialization, we can develop a plan of action and begin to establish mechanisms to systematically support and encourage new technology commercialization. Improved availability of information concerning technology sources and uses, improved screening capabilities, improved incentives for prototype development and commercialization activities, and support for market development are all required activities parts of an effective innovation process.

Most of these problems are managerial and organizational problems and they have not been addressed in the past. Funds for education were not included in the Technology Transfer Acts, for example. These issues are not being researched. I have tried every agency of government to address these problems over the past five years, but have met with the same response, "These are issues are not related to our mission." The narrow "research" focus of government funding agencies has added to our problems of commercialization. I hope that your committee might recommend a change in this narrow view. We need to fund systematic research to solve the "managerial and organizational" problems that we know exist. We need our research and development agencies to begin to address these innovation and commercialization issues as a part of their missions. If we do not, we will not remove one of our most significant barriers: their continued resistance to support applied activities required for commercialization.

Thank you.

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ACADEMIC EXPERIENCE

AUBURN UNIVERSITY (Present)

Dr. Boulton is the Olan Mills Professor of Strategic Management and the Director of The Center For International Commerce at Auburn University. He is currently conducting research to describe the nature of global competition in the pulp and paper industry and teaching courses in Strategic Management.

THE UNIVERSITY OF GEORGIA (1977-1990) ATHENS, GA.

Dr. Boulton was a full-time faculty member at The University of Georgia from 1977 to 1990 as Professor of Strategic Management. In addition to teaching courses in Strategic Management, he taught Business and Competitive Strategy, International Business Strategy, and Innovation and Technology Management courses. He is author of numerous articles and the text, **Business Policy: The Art of Strategic Management**. He has directed dissertations relating to boards of directors, small business and new venture management, competitive strategies to foreign competition, technology transfer, and high technology start-ups.

KEIO UNIVERSITY BUSINESS SCHOOL (1986) YOKOHAMA, JAPAN

Dr. Boulton was resident scholar and Fulbright Research Fellow in 1986 while carrying out research extensive research on Japan's robotics and factory automation industries. This work investigated the competitive strategies of Japanese firms in developing new technologies to meet evolving customer automation needs. This has resulted in a current JAI publication entitled, "Japan's Competitive Strategy: The Move from Technology to Technopolis."

THE SCHOOL FOR INTERNATIONAL STUDIES (1986) **TOKYO**

Dr. Boulton developed executive and conducted training in Business Strategy

THE GEORGIA INSTITUTE OF TECHNOLOGY (1985) **ATLANTA**

Dr. Boulton conducted an special M.B.A. seminar in Advanced Business Strategies.

NORTHEASTERN UNIVERSITY GRADUATE SCHOOL OF BUSINESS (1976/1982) **BOSTON**

Dr. Boulton taught Business Policy and Strategy in M.B.A. and M.A.C.C. programs.

HARVARD UNIVERSITY GRADUATE SCHOOL OF BUSINESS (1974-1977) **BOSTON**

As a doctoral student and research assistant, Dr. Boulton developed teaching materials for Business Policy and Strategy courses. Published cases included "Leisure Group, Inc.," "Northern Industries, Inc.," and "Independent Publishing Co." His dissertation research, "The Nature and Format of Director Information Flows," resulted in a variety of publications.

THE UNIVERSITY OF WASHINGTON (1965-1971) **SEATTLE**

Dr. Boulton completed his undergraduate degree in International Business and Marketing, and his M.B.A. degree in Administrative Organization. His M.B.A. thesis research in the Far East was titled, "The Effects of Culture on Developing a Sales Force in Japan, Taiwan, and Thailand."

PROFESSIONAL EXPERIENCE

ELA TECHNOLOGIES, INC. (1988-present) **ATHENS**

Dr. Boulton is a founding director of this new biotechnology company. He has been involved in all aspects of starting and operating this new high technology firm.

THE UNIVERSITY OF GEORGIA (1973-1987) **ATHENS**

Dr. Boulton served as Director of Graduate Programs in the College of Business Administration. His program changes placed The University of Georgia's M.B.A. program in the top 40 programs in the United States and inthe top position in the southeast as ranked by Business Week magazine .

WILLIAM R. BOULTON & ASSOCIATES, INC. (1981-present) **ATHENS**

Dr. Boulton conducts executive education and consults with senior executives in areas of Boards of Directors, Strategic Planning, Business Strategy and Innovation and Technology Management. He is working with major corporations in developing global technology strategies to deal with global competition.

GTE INTERNATIONAL, INC. (1972-1974) **TOKYO/HONG KONG**

Dr. Boulton was Manager of Market Development for the Far East and served and GTE's sole representative and liaison with two joint ventures in Japan. He was involved in negotiations, joint-venture agreements, organization, staffing, marketing and production management of two joint ventures in Japan. He was involved the implementation of process controls and cost accounting systems, planning for new production facilities and equipment, product planning and marketing programs, and major reorganizations.

SINGER CORPORATION (1970-1971) **FAR EAST**

Dr. Boulton carried out research regarding management and marketing problems in Japan, Taiwan and Thailand. His research resulted in changes in corporate policies and in selection and training of management for Far East position.

Mr. ROEMER. Thank you, Dr. Boulton.

If I could just interrupt for one second and ask the distinguished gentleman from Maryland, Mr. Gilchrest, if he had any opening statement that he wanted to give at this point?

Mr. GILCHREST. Not at this time. Thank you.

Mr. ROEMER. Okay.

The distinguished gentleman from New Hampshire, Mr. Swett?

Mr. SWETT. No statement.

Mr. ROEMER. Okay. Thank you.

Thank you, Dr. Boulton.

Mr. Eldon, if you want to begin, and your entire statement will be entered into the record, and if there are particular things you want to point out and summarize for the subcommittee, we welcome that.

Mr. ELDON. Thank you, Mr. Chairman. Thank you all for coming. Thanks to the audience—thank you to the audience, too. I am surprised and pleased that there is manifest here an interest in what has been described to you as a very serious problem for the United States.

I am here, as you can see from my bio, representing the Institute of Electrical and Electronics Engineers, of which I am one of the 104 past presidents. That is an organization of 315,000 members worldwide. About 250,000 of them are in the U.S., and they are available to you and your call to give testimony and to help out in providing technical advice.

As you can see from my bio also, I have spent my 40-year career primarily, almost exclusively, in manufacturing, and that is the area that I propose to talk with you about. It is one, but not the only, aspect of technology commercialization. I think it is an important one. There have been allusions to it already by the two doctors who have just spoken, and you have mentioned it.

Making the U.S. electronics manufacturing more competitive in the increasingly global economy is going to require concerted effort, of course, by Government, by industry, by academia, by associations such as IEEE, and by individuals. Specifically, to summarize my views here this morning, I believe that the Government should take action in three areas.

The first area is in education. You all know, as I do, that the K through 12 education program in the U.S. for math and science is a virtual disaster area. Particularly compared with Japan, we turn out the kids according to standardized international tests that are in the bottom of the developed countries. The Japanese turn out kids on these standardized tests who are at the very top of the programs among developed countries, and I can assure you, from my 40 years of experience and actually doing manufacturing and in supervising manufacturing, the knowledge of those topics is essential for productivity increase. I hope that the Congress, you included, will support all the programs that have been proposed to fix that problem.

I have described in addition in my presentation here, which you have in writing, in addition to the problems in K through 12, other problems, different ones in junior colleges, in undergraduate engineering programs, and in graduate engineering programs. To solve these separate problems, I have made the following recommenda-

tions for Government actions: A, to encourage apprenticeship programs; that helps in the matter of teaching people how to do things as opposed to just academic subjects, and I think, Mr. Roemer, having taught that or being knowledgeable about it, will be sympathetic to the idea of apprenticeship programs, manual arts, and that sort of thing.

B, I think we should provide more scholarships for science, and, as the other gentlemen have said, primarily engineering students, particularly those in manufacturing. There are few scholarships, there are few programs, in manufacturing engineering so far in the United States by contrast with, for instance, as was mentioned, Japan and Germany.

C, I think we should support continuing education programs for technologists of all levels in industry, and there can surely be some Government programs that would help out in that continuing education field.

And, D, I think we should have some sort of legislation for a requirement that perhaps the foreign students who come here, that they pay the full cost of the education that they get in our graduate schools, which they don't right now, and that they have an opportunity to work here for a number of years equal to the number of years they go to school here. Singapore has that kind of requirement already. I notice in the American Technical Preeminence bill that there is a proposal that NIST be allowed to hire foreigners who get their graduate engineering education in this country so that we can have use of their skills before they go home to compete with us.

A second area that I want to make some remarks about concerns support for consortia. A major problem of U.S. manufacturing companies is to have viable legal ways to share in the development of technology, and during the past few years, as you may be aware, we have experimented with organizations that we call consortia. However, most of these consortia have focused on areas in which the U.S. already excels—namely, as was pointed out, advanced research. Only Sematech is vertically integrated as a consortia of a dozen or so companies. Only it emphasizes in particular manufacturing innovation, and, furthermore, all consortia, Sematech and all the others, have been established as permanent organizations with a very broad agenda.

By contrast, the Japanese consortia—and there have been a great many of them started during the past few years—have been organized for relatively short periods with highly focused agendas related to establishing feasibility of developing new products and new processes—just what you mentioned, Dr. Boulton.

I believe that manufacturing productivity and U.S. competitiveness would be enhanced if the Government would support Sematech and all other similar consortia that (a) focus on practical technology as opposed to pure science, with specific narrow purpose, and (b) when they emphasize information exchange leading to demonstration of product and process—that is, manufacturing feasibility—especially in emerging technologies, and (c) when they are established for specific, finite lifetimes.

The third area, which is much more focused than the previous two that I have mentioned and I want to make some comments

about, is the area of microelectronics. Microelectronic components, mostly, but not exclusively things that you all know as chips, are everywhere. They are, and they will remain in the next two, or three, or four decades, the largest dollar value and the most important performance contributors to the electronics industry, and although semiconductor memories were developed in the U.S., 70 percent or so of them now are made in Japan. There are a number of other components, microelectronic components, where even higher percentages of the products are made in Japan, and you all know—you mentioned, Representative Roemer, in your initial remarks—the effect that has had on U.S. commercial electronics industries.

As you pointed out, we buy most of our radios and our TV's and our VCR's and our video cameras and the like from Japan, and now, as you may be aware, Japan is close to gaining control of the computer industry. They are going to get that control primarily because they are able, by having large volume productions of microelectronic components, to have inexpensive, high quality components at state of the art.

Some actions that the government could take that would support U.S. capability in the manufacturing of microelectronic components are: A, to steer the federal expenditures into study and development of manufacturing processes and equipment—and equipment, at Sematech, at the national labs, at universities, and even at private industries through such programs as the ATP Program that you are proposing within the National Institute of Standards and Technology. The various recently published lists of emerging and critical enabling technologies can be used to help prioritize among those alternative opportunities.

B, I think we should have Government support to increase the use of U.S.-produced microelectronic components in Government systems. I am sure you read, as I did, that in the recent activity in the Persian Gulf a lot of these esoteric defense products that were used to make us look awfully good contained components that were built elsewhere, mostly in Japan, but in Germany, and in South Korea, and so on. We should make an effort to have them built here in the United States.

The third: As an example, I hope that you will expedite approval of a single U.S. standard for high definition television.

These three things—the HDTV and U.S. products used in Government systems and so on—are going to give U.S. microelectronic manufacturers a chance at volume production ahead of our international competitors.

We also recommend from the IEEE that the Government enforce strongly, as it has not done yet, the intellectual property rights of U.S. companies and inventors and that you develop, as you pointed out, as Mr. Thornton alluded to, a strategy to assure the U.S. sources for manufacture of state-of-the-art microelectronic components under all possible scenarios.

Thank you for your consideration of these remarks. I am looking forward to having a discussion with you, and I'm looking forward to the opportunity for the IEEE U.S. members to assist you as a resource for technical advice and policy perspectives on the full range of issues related to U.S. competitiveness.

[The prepared statement of Mr. Eldon follows:]

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Promoting Career and Technology Policy Interests of Electrical, Electronics & Computer Engineers

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STATEMENT

by

MR. CHARLES A. ELDON

PAST PRESIDENT AND ELECTED FELLOW
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

to the

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS
COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

on the

ACCELERATION OF U.S. TECHNOLOGY COMMERCIALIZATION

May 7, 1991

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May 7, 1991

Good morning, Mr. Chairman and Members of the committee. My name is Charles A. Eldon, and I am a past president and elected Fellow of the Institute of Electrical and Electronics Engineers (IEEE). I am grateful for this opportunity to present the views of IEEE-United States Activities on needed steps to accelerate U.S. technology commercialization and enhance U.S. competitiveness.

I have spent my 40-year career in electronics manufacturing. This is the only area that I propose to discuss. That is not to ignore the many other aspects of U.S. competitiveness. I endorse the recommendations of the 1987 U.S. Competitiveness Commission -- the so-called Young Commission -- and of course, the IEEE-USA Federal Legislative Agenda, with which I hope you are familiar. Hopefully, others will address those other aspects.

According to the Department of Commerce, U.S. productivity declined .8 percent last year. That was the sharpest decline since a .9 percent drop in 1982, and it followed a .7 percent decline in 1989, for the first back-to-back retreat since 1979-80. In other countries, notably Japan, manufacturing productivity has continued to increase. Electronics is included in those data.

The worldwide market for electronics products is approximately $800 billion. It is the largest industry in the U.S. and its products are ubiquitous; so manufacturing competitiveness in electronics is fundamental to our economy.

Making U.S. electronics manufacturing more competitive in the increasingly global economy will require concerted action by Government, industry, academia, associations such as IEEE, and by individuals. Specifically, I believe that our Government should take action in three areas:

1. EDUCATION

You know that K-12 education for math and science is a disaster area in the U.S. Our children score dead last among developed nations in those subjects. (Incidentally, Japanese children score first). I assure you from my 40 years of doing or supervising electronics manufacturing that all but the most menial jobs absolutely require an understanding of basic math (with some understanding of statistics), and that knowledge of the fundamentals of physics and chemistry are extremely helpful. Yet a small percentage of our high school students study any of these subjects beyond arithmetic. I hope that the Congress will support ALL programs to fix this situation.

Other than a few community college programs, and learning on the job, there are very few ways in which a person can learn manufacturing skills. Unlike European countries and Japan, we don't have many apprenticeship programs. Within our schools, students are stigmatized if they take "shop" courses, rather than "academic" courses. Almost no one prepares for manufacturing jobs.

At the undergraduate level, even in the best engineering schools, there is a dearth of "manufacturing" training. Few professors have manufacturing experience; facilities are expensive and in short supply; and, research and development is favored, while manufacturing is denigrated. The consequence is that few engineering or science graduates are prepared for manufacturing jobs. By contrast, in Japan the top graduates go into manufacturing.

Our graduate programs in science and engineering, by contrast, are a huge success. During the past decade, more than half of the Ph.D's in science and engineering have gone to foreigners. Many of them stay in the U.S. by taking positions as teachers in our universities. But their cultures generally lead them into theoretical research, as opposed to manufacturing subjects. Moreover, they often lack English language skill, further inhibiting their effective communication to students. Others return home and end up competing with U.S. companies. Since tuition covers less than half the cost of college education, foreign students paying full tuition are subsidized by taxpayers.

To solve these problems, I recommend the following Government actions:

- o Encourage apprenticeship programs.
- o Provide more scholarships for science and engineering students -- particularly those majoring in manufacturing programs.
- o Support continuing education programs for technologists in industry.
- o Legislate a requirement that foreign students both pay the full cost of their U.S. education and work here for the number of years that they go to school in the U.S. Singapore has this requirement.

2. SUPPORT ESTABLISHMENT OF INTEGRATED CONSORTIA

A major problem of U.S. manufacturing companies is to have viable, legal ways to share in the development of technology. During the past few years, we have experimented with organizations we call consortia. However, most of these consortia have focused on areas in which the U.S. already excels, namely advanced research. Examples in electronics are MCC (Microelectronics and Computer Technology Corporation) and SRC (Semiconductor Research Corporation). Only SEMATECH is vertically integrated, emphasizing in particular manufacturing innovation. Furthermore, all of our consortia have been established as permanent organizations, with broad agendas.

By contrast, Japanese consortia -- and there have been many during the past several decades -- have been organized for relatively short periods, with highly focused agendas related to establishing feasibility of developing new products and/or processes. In particular, they emphasize providing a technological basis for continuous manufacturing improvement, paying attention to production and design driven commercialization.

I believe that manufacturing productivity and U.S. competitiveness would be enhanced if the Government would support SEMATECH and other similar consortia that:

- o focus on practical technology, as opposed to pure science, with specific, narrow purpose;
- o emphasize information exchange, leading to the demonstration of product and process (manufacturing) feasibility -- especially in emerging technologies; and,
- o are established for specific, finite lifetimes.

3. SUPPORT MICROELECTRONICS

Microelectronic components (mostly - but not only - things called "chips") are everywhere. They are, and will remain, the largest dollar value and most important performance contributors for the electronics industry. Although semiconductor memories were developed in the U.S., 70 percent or so of them now are made in Japan. Less well known is that 90 percent of resistors, capacitors and microelectronic package substrates (ceramic pieces), most solid state computer displays, most raw wafers, and most of many other components are also made in Japan. One does not make any electronic products without most of these components. We buy them from Japan.

You know what effect that has had on the U.S. commercial electronics industry. We buy most of our radios, TVs, VCRs, and video cameras from Japan. Japan is close to gaining control of the computer industry. Computers control our ability to obtain, distribute, and use knowledge. Loss of competitiveness in that vital market would have a huge impact on our defense position, all U.S. companies that use computers, and on our educational system. Thus, microelectronics is critical to our whole society. It is the sine qua non.

It is very difficult to make these microelectronic products. I have done it. It requires a great many separate manufacturing operations. Each requires use of sophisticated equipment. Each operation affects all other operations, because they are done sequentially on the same material. Each operation must be done very carefully in order to get any finished product.

Let me illustrate. Suppose one does each operation correctly 90 percent of the time and that there are five sequential operations. At the end of this line, you will only have a 60 percent yield (.9 x .9 x .9 x .9 x .9 = .59). For 100 operations, given an average 90 percent accuracy, almost nothing will be produced!

The objective in making microelectronics components is to improve yield at each manufacturing step. That requires well trained people using the best available tools, equipment, and materials, with the best possible controls. The capability of equipment (design, adjustments, control, and operation) to make microelectronic components also improves with practice - just like in tennis, or golf, or painting.

In my personal experience, the yield in making integrated circuits sometimes improved as much as 30 percent every time the cumulative quantity doubled. Thus, volume production is important.

Unfortunately for the U.S., most volume production of microelectronic components is in Japan, because they have followed a strategy of making products for high volume commercial applications. That means that their yields are higher than ours. Their production workers get more practice than ours, and their equipment has been re-designed and adjusted and controlled to maximize its performance. Most of the best available equipment for use in making microelectronic components comes from Japan. Often U.S. companies get to buy that equipment after it has been used for much production in Japan; i.e., after they have achieved doubling of production. So we are often behind them on the learning curve.

Furthermore, Japanese companies are spending much more than U.S. companies on development of improved microelectronics manufacturing equipment (projection alignment, lithography, evaporation, component handling, surface mount assembly, tape automated bonding, etc.).

Finally, we must recognize that where manufacturing capability is maximized, engineering design will follow. Witness the engineering for TVs, VCRs, cameras, etc. We must maintain the ability to manufacture microelectronic components at world class levels of cost, quality, and performance, in order to be able to maintain our ability to design and engineer electronic products at world class levels. Otherwise, the U.S. ultimately will simply become users of virtually all electronic products, as we already are of TVs, VCRs, etc. Unfortunately, that would include most critical defense systems, as well as computers.

Some actions that the Government could take that would support U.S. capability in the manufacture of microelectronic products are:

- Steer Federal expenditures into the study and development of manufacturing processes and equipment at SEMATECH, the national labs, universities, and even private industry through programs such as the Advanced Technology Program within the National Institute of Standards and Technology. The various recently published lists of emerging and critical enabling techologies can be used to help establish priorities.

- Increase the use of U.S.-produced microelectronic components in Government systems. Specify development of unique products, then encourage the transfer of these to commercial products (e.g. displays, photonics, optics, ICs).

- Expedite approval of a U.S. standard for High Definition Television.

These actions would give U.S. microelectronic manufacturers a chance at "volume" production ahead of our international competitors. We also recommend that Government:

- o Enforce STRONGLY the "intellectual property rights" of U.S. companies, for both software and designs.

- o Develop a strategy to assure U.S. sources for manufacture of state-of-the-art microelectronic components under all possible scenarios.

Thank you for your consideration of these remarks. The IEEE-USA stands ready to assist you as a resource for technical advice and policy perspectives on the full range of issues related to U.S. competitiveness.

Mr. ROEMER. Thank you, Mr. Eldon. We will take you up on that offer.

Mr. Elkus, your entire statement will be entered into the record, and please summarize in whatever fashion you deem appropriate for your remarks.

Mr. ELKUS. Thank you.

First of all, I would like to extend my appreciation to the members of the committee for inviting me here. This is not the first time I have testified on this subject. To anybody who has ever heard me before, I hope I don't bore you.

I also would like to say that I think because of a mistake that I made I didn't bring copies of this statement, so does everybody have a copy up there?

Mr. ROEMER. Yes.

Mr. ELKUS. Before I begin my specific statement, I would like to give some of my background only because I think it helps illustrate some of the reasons why I say what I do.

In 1970, I had the pleasure, at least at that time, of introducing the VCR to the world. I was a member of Ampex Corporation, assistant to the president, headed the Educational Industrial Products Division, and wrote the original product plan, and then headed the engineering teams that introduced that product. So it is a product I am familiar with, and, as such, I spent a fair amount of time in Japan involving myself with most of the key companies and the key leaders of those companies who were also interested in coming up with a product of a similar nature.

Recently, I completed a study where I chaired a National Science Foundation panel on high definition products and systems which relates directly to high definition television, and if later on in the discussion you wanted to get into that at all, it is an area that I have some feel for.

I am currently chairman of a company called Prometrix. We manufacture semiconductor equipment. I am also chairman of a company called Integrated Systems, which is involved in a very high level software field called CAE—computer-aided engineering—and CASE—computer-aided software engineering. Aside from that, I am on the advisory board of the Center for Strategic and International Studies; I am a director of the American Electronics Association.

With respect to this particular testimony, I am giving you my own personal thoughts. To the extent that they reflect anybody else's, it is by coincidence, I'm sure.

I wrote in the statement that I gave, the written statement called "The Strategy of Leverage," the following: "The United States operates on the theory of opportunity cost: If you can make more money elsewhere, do it. Japan feels that walking away from the development of end-use products and markets based upon the strategy of opportunity cost destroys the economic infrastructure of inter-related products and markets that is fundamental to technological development. It is felt that such a strategy will only enhance the relative position of the competition.

"During the 1940's and 1950's, three United States companies created industries that became the foundation for many of the strategic world markets of today. RCA was instrumental in the devel-

opment of television. Shockley Transistor Company spawned the semiconductor industry. Ampex Corporation developed the field of magnetic recording. Today, television, telecommunications, computers, consumer electronics, and mass media have a significant portion of their roots in the contribution of these three companies.

"As of 1970, America was virtually self-sufficient as a nation. It encompassed the world's biggest market, produced more products, and had the largest trade surplus of any nation on earth. America's currency was one of the most solid in the world, and America's banks were the biggest.

"Today, only one U.S.-owned company produces television sets (not RCA). The television market is dominated by Japan and Europe. Today the United States is virtually a nonparticipant in the market for audio and video recording. Today the United States is no longer the largest producer or clear technological leader in semiconductor design and manufacture. The United States surplus balance of trade in computers is less than half of what it was in 1981. Moreover, America has a negative balance of trade in computers and related products with Japan.

"In a chart entitled 'U.S. Report Card: Trends,' the Technology Administration Branch of the U.S. Department of Commerce in their spring of 1990 report on 12 emerging technologies noted that in comparison with Japan the U.S. was:

"Losing Badly in Advanced Materials, Biotechnology, Digital Imaging, and Supercomputers

"Losing in Advanced Semiconductor Devices, High-Density Data Storage, High-Performance Computing, Medical Devices, Diagnostics, Optoelectronics, and Sensor Technology

"Holding in Artificial Intelligence, Flexible Computer-Integrated Manufacturing

"And gaining in none."

At this point, I'd like to depart from comments included in the first page of my written testimony entitled "The Strategy of Leverage" and give you an insight that I believe I have in the future of the automobile industry. All of this is to illustrate a point.

Everybody has read articles over the last several months, maybe years, about the problems in the U.S. automobile industry. I testified last year to the Senate Banking Committee, along with Don Peterson, former chairman and CEO of Ford, and Henry Schacht, chairman of Cummings Engine, and it was discussed at that time that the automobile industry was having its problems in various ways.

It has been pointed out in many articles in the Wall Street Journal and elsewhere that the number of plant closings by U.S. companies in the United States have virtually equaled the number of plant openings by Japanese manufacturers, and for the last several years the United States automobile industry has constantly lost its share of market to foreign competition.

I believe that the automobile industry's future—that is, the U.S. automobile industry's future—is relatively bleak, and I believe that if, in fact, we lose our position of strength and proportion in the field of automobile manufacture it will not be because of lack of productivity, it will not be because of lack of efficiency, it will not be because of lack of reliability of the product, all factors which

have been discussed before. It will be because we are unable to manufacture an automobile which is competitive in terms of the features required by the consumer that will be manufactured by our competition, and let me explain why.

When I completed our report, or when we completed our report, for the National Science Foundation, we did so after a brief trip to Japan where we met with certain leaders of various companies discussing high definition products and systems. At one of the meetings in Matsushita, we were handed a brochure, a book, which included hundreds and hundreds of products that were under development by the Matsushita laboratories. These products were clearly stated products that were going to be coming out over the next five years. They were pointed out in terms of features, the interrelationship of each of the products to each other, the implications to the long-term future of Matsushita as a corporation and Japan as a country. They were done in such a way that almost anyone who really was interested could determine where Matsushita's laboratories were going over the next several years, something that you don't see in an American company.

One of the sections of that book discussed the automobile industry. Now, as you know, Matsushita is not in the automobile business. Matsushita produces VCR's, microwave ovens, refrigerators, materials, semiconductor devices, all types of consumer electronics. They do not produce automobiles, but there was a sector on automobiles in the Matsushita book, and from that section an advertisement was lifted and almost a direct reproduction of one of the pages appeared in most of the key magazines, business magazines, in the United States, including Business Week, Fortune, Newsweek, and several other publications. Let me tell you briefly what the advertisement said.

It said that the automobile of the future was going to be connected to your home and to your office so that an individual sitting in a car could effectively tell what was going on in his home or his office, communicate at all times, could determine where he was—that is, the individual driving the car could determine where he was, where he was going, what the road conditions were, could automatically and at his discretion, or her discretion, set the temperature in the microwave oven, set the temperature in the house, turn on or off your alarm system, open or close your garage door, communicate in whatever language, verbally, that you wanted to via telephone, totally voice activated, have video communications with whomever, mobile fax machines, mobile VCR's, et cetera.

Now the point of all of this is as follows. Those products manufactured by Matsushita and, I might add, any number of different companies in Japan are all becoming integrated with each other and with other products that seem to be far afield. So, for example, the microwave oven is becoming integrated with the automobile, the idea being that man should always be in touch with his total environment and able to control his environment.

Now it just so happens that virtually none of the products that are referred to by Matsushita and other companies in Japan are manufactured any more in the United States. Consequently, if Ford or General Motors or Chrysler wish to compete on an equivalent basis with a Japanese company, they must effectively either

buy components from that Japanese company, a company who is competing with them in the end use market in other product areas, or not effectively have a product at all.

Now as time goes on, the integration of these products is becoming so complete that it requires tremendously close cooperation in the development of these integrated efforts, the result being that, not only from a cultural standpoint, language standpoint, or just being in the vicinity, Japanese companies will tend to cooperate with each other much more easily and completely than they will with a U.S. company.

If you can imagine an automobile company in the United States trying to compete with a Japanese company who is also selling him the components to make him more competitive in the end use product, the answer is, it isn't going to happen. I can tell you any number of circumstances where you can see over time that the level of product that is coming to the United States from our competition overseas at a higher level are not quite as good or quite as timely as the products that are included in the end use market of those products produced, for example, in Japan, and this is only as it should be. No company in the United States wants to ensure the success of its competitor at the expense of itself totally, so there is always a level of lead, there is always a level of extension of capability, that exists in the host company producing products key to other products around the world that says, "I'm going to protect my market first; otherwise, I won't be in business for the long term."

In that regard, let me make one other comment, and then I would like to make a conclusion. In the United States, we look at long term as five to 10 years and short term as milliseconds. In Japan, long term is forever. Long term is in perpetuity. That one concept alone changes every single ground rule that exists as we look at our competitive situation.

Let me make some other concluding remarks based upon that. We have a penchant—and to some extent I make my business out of this—of concentrating on the concepts of technology. Technology follows markets, not the other way around. There is no such thing as a revolutionary development that is going to change the world. It is evolution, not revolution, that makes competition very, very difficult.

The VCR was probably, if you want to call it that, as revolutionary a development as you could imagine in terms of what it did to communications, to the semiconductor industry, to optics, to recording, to data storage and retrieval, to all of the base markets which we today call information systems, and yet I assure you that the VCR is a series of little, teeny steps taken over many, many years.

In 1970, when Ampex introduced the VCR, the total number of video recorders produced in the world was 15,000 units a year. The average price of those units was somewhere around $10-100,000 a copy, depending upon what market you were looking at. The products were relatively unreliable; the performance was reasonable. Over a period of time, the Japanese worked on the VCR and all of the component parts.

Remember that a VCR includes parts of a 35-millimeter camera as we see it today, parts of an audio recorder, whole bunches of parts in the semiconductor industry and related areas of activity, tremendously involved in materials and ceramics and things of that sort.

By 1985, the Japanese were producing 2.5 million units per month, and the cost of those units was running in the neighborhood of $200 a copy. The United States, which represented 75 percent of the market in 1970, represents less than a percent today. All of the companies producing VCR's produce those VCR's under license to Ampex and to U.S. companies.

The point I am making is this. Technology follows markets, not the other way around. If I own major pieces of markets and these markets join together and become stronger as they become developed over time, I will absorb your technology, no matter how good it is, because you will have no place to put it, no place to sell it, so you will come to me. Because of that, I don't really care about intellectual property rights; I will get your intellectual property rights because you are going to sell them to me at what some day will be dimes on the dollar because I am the only person in town that can use it.

Let me explain the cost of technological development. We look at it as investments at a given point in time of a certain amount of dollars, but that is not how technology is developed. Imagine this. In Japan, you have a product called a 35-millimeter camera. Bell and Howell monopolized that market at one point in time, Kodak. We don't make them any more. On the other hand, you have a video recorder—what do you call it?—a Betacam system, or whatever—you know, a VCR and the camera all in one. Imagine that you take the electronic imaging system from the VCR and you drop it into the 35-millimeter camera so now you can take a still frame picture and record it on magnetic media as opposed to film. Lots of interesting things can be done because of that. You can either have a hard copy, like you would a regular picture, or you can show it on your TV set, you can erase it and do it again 500 times, 1,000 times, it makes no difference; you can transfer it then electronically any number of different places, et cetera.

The cost of doing that in the United States, coming up with that product, a combination of the VCR and the 35-millimeter camera, is billions of dollars. The cost in Japan is virtually nothing. The time to develop it in Japan is virtually nothing. There is no way of calculating the cost that we are unable now to duplicate in this country for whole sections of technology which are gone because the interrelationships of these products and markets are no longer available to us. The infrastructure is gone, because we have centered on the concept of opportunity cost: If you can't make enough money here, you get out of this and you go into that. Pretty soon, you find out that whatever is left depends upon all those things that you sold off, and you are out of business.

So what is my conclusion? Technology, intellectual property rights, our educational system itself, depends upon our situation, our position, in products and markets as mundane as, for example, consumer electronics. Without positions in those markets as they become closer and closer allied over time, we will lose the industri-

al base of our country irrespective of how much money we attempt to invest in technology; irrespective of whatever consortium we put together, there isn't enough money around.

The cost of developing the VCR in 1970 in terms of research and development was about $2 million. To build a factory today to produce VCR's would cost you in excess of $600 million. But that factory means nothing, because if you don't have the optics business, if you don't have the semiconductor business, the materials business, the 35-millimeter camera business, the audio business, the compact disc business, the television business, you can't produce a VCR.

Motorola produces this Microtac telephone. Today, Mitsubishi and Fujitsu have come out with systems that have twice the battery life and much smaller size. Part of the problem that Motorola faces is that the infrastructure that feeds Japan doesn't exist in the United States in the various component parts that fit in this camera unless Motorola wants to do it all itself.

Batteries are critical. Every major company in Japan in the electronics business has either a direct hold on or a very closely related activity in the battery business, which is advancing at an alarming rate from a commercialized standpoint compared to anything that exists in the United States.

The point of all of this is simply the common sense concept, without markets you have no technology, without markets you have no intellectual property rights. Until we change the ethic, until we change the culture, until we change the strategic understanding of the interrelationship of products and markets that exists in this country today, we will continue to lose our industrial base. The cost of changing that and going the other way over time will become so great that it could ultimately affect our political system, our ability to protect ourselves, our ability to be other than a Third World power.

Thank you.

[The prepared statement of Mr. Elkus follows:]

THE STRATEGY OF LEVERAGE

Richard J. Elkus, Jr., Chairman
Prometrix Corporation

The United States operates on the theory of opportunity cost: If you can make more money elsewhere, do it. Japan feels that walking away from the development of end-use products and markets based upon the strategy of opportunity cost destroys the economic infrastructure of inter-related products and markets that is fundamental to technological development. It is felt that such a strategy will only enhance the relative position of the competition.

During the 1940's and 1950's, three United States companies created industries that became the foundation for many of the strategic world markets of today. RCA was instrumental in the development of television. Shockley Transistor Company spawned the semiconductor industry. Ampex Corporation developed the field of magnetic recording. Today, television, telecommunications, computers, consumer electronics and mass media have a significant portion of their roots in the contribution of these three companies.

As of 1970, America was virtually self-sufficient as a nation. It encompassed the world's biggest market, produced more products and had the largest trade surplus of any nation on earth. America's currency was one of the most solid in the world, and America's banks were the biggest.

Today, only one U.S.-owned company produces television sets (not RCA). The television market is dominated by Japan and Europe. Today the United States is virtually a non-participant in the market for audio and video recording. Today the United States is no longer the largest producer or clear technological leader in semiconductor design and manufacture. The United States surplus balance of trade in computers is less than half of what it was in 1981. Moreover, America has a negative balance of trade in computers and related products with Japan.

In a chart entitled "U. S. Report Card: Trends", the Technology Administration branch of the U. S. Department of Commerce in their Spring of 1990 Report on twelve emerging technologies noted that in comparison with Japan, the U.S. was:

- Losing Badly in Advanced Materials, Biotechnology, Digital Imaging Technology and Supercomputers

- Losing in Advanced Semiconductor Devices, High-Density Data Storage, High-Performance Computing, Medical Devices and Diagnostics, Optoelectronics, and Sensor Technology

- Holding in Artificial Intelligence, Flexible Computer-Integrated Manufacturing
- Gaining in None.

The change in balance of economic power between the United States and Japan over the last 45 years has been staggering. In the view of R. Taggart Murphy as expressed in the March/April issue of the Harvard Business Review, "Japan today sits on the largest cache of wealth ever assembled."

Why a change of this magnitude in such a short time? Imagine that products and markets are like links in a chain. If you take a product and carry its development to a logical extreme, it becomes related to other products. For example, the optical system on a 35mm camera is similar to the optical system on a video recorder. Conversely, the electronic imaging system that is common to a video recorder is now beginning to be substituted for film in a camera.

Similarly, if you develop a market to its logical extreme, it becomes related to other markets. For example, the development of the market for VCRs made possible the market for pre-recorded videotape which is now a larger market than that of film in theatres. Conversely, if manufacturers of pre-recorded videotape choose one VCR format over another for their programming, that choice tends to influence the popularity and growth of the market for VCRs. Thus, like links in a chain, products and markets become inter-related and inter-dependent as they are developed.

In the electronics market there is one component common to virtually all electronics products - the semiconductor. Control enough links in the chain such as the markets for video recording, cameras, audio recorders, television, and computer products, and you become predominant in semiconductors. Become predominant in the design and development of semiconductors, and your prowess as a developer of other electronic products and markets increases substantially. Electronic products are fundamental to virtually every market there is. Thus, a chain of markets linked together begins to control a technological base of such significance that competitive re-entry is very difficult and expensive.

One often hears how we must improve our technological base. Technology follows markets, not the other way around. If you own the technology, but lose the market, you will lose the technology. Ampex introduced the video tape recorder in 1956 and the VCR in 1970. As a company it had a virtual 100% hold on patents in the field. Ampex decided not to pursue the VCR market. That market was picked up by the Japanese. With that market went not only the majority of video recording but a major segment of the support technologies including the design and manufacture of semiconductors.

The development of high definition products (for example, HDTV) by the Japanese represents a major improvement in the processing of large amounts of audio visual information. High definition products will touch virtually every

aspect of human creativity. For example, high definition television doubles the horizontal and vertical resolution of television providing five times the visual information and as a result, spectacular pictures and sound. These advancements are made possible in part by major improvements in computer display and semiconductor technology.

Because of the breadth of applications and cost of development, no industry, technology or company will be able by itself to meet the challenge and opportunities of high definition products and systems. As the compact disk redefined the music industry, high definition products will redefine mass media. With major advances in digital technology, high definition products will redefine computers and their applications. With alternate means of transmission, high definition products will redefine the broadcast industry, shopping, medical electronics, education and banking.

As Japan introduces a full line of high definition products, it insures itself of major advancements in: cameras and recorders, fiber optics and satellite transmission systems, VCRs, computers, flat screen displays and semiconductors--all markets in which it has a major if not commanding position.

The infrastructure in electronic products and systems (now in place in Japan) will ultimately become one with that of the media and telecommunications services as the ability to process massive amounts of audio visual information increases. This is part of the reason for Sony's interest in CBS Records and Columbia Pictures.

As the Japanese position in strategic interrelated end-use markets has improved. the cost of competitive re-entry by others has often become prohibitive. This, in large part, has occurred because of the interrelated nature between products and markets. Today individual products and markets are really a combination of many interrelated technologies, components, products and markets. For example, the technology of putting pictures on tape was of supreme importance 20 years ago. But now, high levels of sophistication in digital signal processing, display technology, camera and optical know how, semiconductor technology, computer technology, high-volume fully-automated manufacturing capability and mass marketing, sales and distribution systems are required to compete in the market for video recording.

But other costs also rise. For example, the development of a semiconductor device that cost a few million dollars a few years ago may cost in excess of a billion dollars today. Similarly, the cost of a VCR facility 20 years ago would have been less than $10 million. Today that facility might cost as much as $600 million.

Hence, while the United States may be willing to drop a product or market on the basis of "opportunity cost" and reinvest in a more lucrative enterprise, Japan will often do just the opposite. Because of the concept of relationships between products and markets, the Japanese feel that to abandon a product or market means the potential loss of other related products and markets and, therefore,

the loss of valuable infrastructure. It is this infrastructure--that is, strategically related end-use products and markets--that provides the basis for future economic growth and development. The concept of relationships and infrastructure is common throughout Japan and is fundamental to the acceptance of and necessity for long-term planning.

Assuming that the combination of the markets for electronics, telecommunications and media is the basis for entry into the information age, the following conclusion should be considered: Any significant loss of infrastructure of end-use products and markets within the area of electronics, telecommunications and media may substantially reduce the growth potential of an economy dependent upon that infrastructure. The Japanese feel, and statistics tend to bear this out, that the infrastructure represented by the markets for electronics, telecommunications and media are of major significance to the economic and political development of the United States, Japan and Europe. Lose control of one, and you may lose control of both.

Can the U.S. turn the tide in its favor? Absolutely. The U.S. computer industry is still dominant. America's position in mass media, software and transmission services is still solid. These markets can provide a basis for restoring America's competitive position. But such an effort must also include strategic moves back into consumer electronics, display systems, audio and video recording, computer peripherals, components, and related technologies. Otherwise, the combination of developments in high definition products and those markets America has lost will continue to encroach on remaining U.S. positions of strength.

One definition of chaos is fear without strategy. Rapid changes in the balance of economic power between nations without an appropriate strategy to address that change creates economic and political uncertainty. Uncertainty breeds fear.

Couple a modicum of fear with strategy and the United States can again be the most competitive nation in the world. On the other hand, allow fear to reign without strategy, and American leadership is up for grabs.

RICHARD J. ELKUS, JR.

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Production Control Manager, Ampex Corporation, Redwood City, CA from 1959-1964; Assistant to President 1968-1971; Member of Operations Board, 1969-1971; General Manager Educational and Industrial Products Division, 1969-1972 (1970-Introduced America's first entry into the VCR market.)

President, Chief Executive Officer and Director, Eyrie Company, Santa Clara, CA 1964-1967

General Manager, Gould Medical Systems, Santa Clara, CA 1973-1974

Executive Vice President and General Manager of Geometrics, Inc., Sunnyvale, CA 1974-1980

Director of Acacia Sales Corporation, Sunnyvale, CA 1973-1983

Director Pacific Measurements, Inc., Sunnyvale, CA 1974-1983; Chairman, 1980-1983

Chairman, Chief Executive Officer and Director, Prometrix Corporation, Santa Clara, CA 1983-Present

Director and Chairman of the Board of Integrated Systems, Inc., Palo Alto, CA 1985-present

Director and a Founder of Tomex Corporation, Sunnyvale, CA 1982-1987

Member ex-officio N.H. Governor's Fee Schedule Committee 1958-1959. Served to capt. USAR, 1957-1965

Chairman, National Science Foundation Panel on High Definition Products and Systems, Co-Chair American Electronics Association Committee on High Definition Television

Vice Chairman, Government Policies Committee (High Resolution Systems Task Force - Defense Manufacturing Board)

Member Past or Present: American Electronics Association, American Management Association, Electronics Association California, Semiconductor Equipment & Materials International, SEMI/SEMATECH, Association for Corporate Growth, U.S. Chamber of Commerce, Council on Competitiveness

Mr. ROEMER. Thank you, Mr. Elkus.

I would just like to, on behalf of the entire committee, thank all of the panelists for their cogent, and articulate, and insightful testimony, and also for their personal insight, too. I wish that I could take all four of you to my district to articulate much better to my constituents what a vital aspect of our future this issue is for us today, and it is one of the reasons that the chairman has called for these hearings, and we will get on with the questions but, again, thank you very, very much for your participation today.

As all of you have pointed out, it is very important for us to look beyond the factor floor to maintain our competitive edge here, whether it be our public education system, whether it be monetary policy in this country, whether it be incentives that we look for to encourage capital formation. All these things are very, very important for us in the future.

One of the things our committee has looked at in the past is how we commercialize the results of what is produced in our labs, the Department of Energy labs in Brookhaven, for instance, and some people on our committee and in Congress and throughout the country also think that many of these things ultimately are business decisions.

I would like, maybe Dr. Guile, for you to start. Are they, in fact, business decisions? And then, secondly, how important is monetary policy, microeconomics, macroeconomics, in gauging these decisions in the future for us?

Dr. GUILE. Thank you for the opportunity.

I put some thought after I got asked to serve as a witness as to what I would talk about Government policy questions based on the work we have done, and I have spent probably 10 years of my life writing reports recommending different policies, so I am familiar with the long litany of antitrust and direct support for research, and, frankly, at the end of the day I came down to sort of negative findings more than anything else, and I decided that what I really wanted was a game show buzzer so that you can interrupt people when they say things.

In particular, I think that you have heard from all of the witnesses today that we often jump too quickly from a discussion of commercialization to a discussion of research and development, and I really would like a game show buzzer to interrupt that link, because I think most of the commercialization problems, as we have heard today, are not a question of basic research, they are a question of business practice, as you pointed out.

I think the next place I would like to say that there is a negative finding is, to think that this is an issue that we can solve domestically is probably incorrect, and the reason I'll say that is, if you will think about the kinds of examples that we have heard about—the ability to integrate different technologies to produce new products—we are no longer the only player in the world in terms of technological competence, and anybody who is going to play in world markets has to be able to overcome what people call an American disease, which is the "not invented here" syndrome and scan and pull technologies from all over the world into their business. I think we have heard an eloquent description of the importance of being able to do that from Mr. Elkus.

The third negative finding in terms of Government policy is, quite apart from whether or not you believe there are critical technologies—personally, I believe there are critical technologies, and we have seen a proliferation of lists of critical technologies—but quite apart from whether you think those exist, it is relatively clear that no amount of support to or for specific technological areas is going to translate easily into commercial capability that is going to overcome the problem with commercialization.

So I really want a buzzer to interrupt those three different easy statements. It is not research, it is not a domestic problem, and focusing on critical technologies won't make it go away.

Mr. ROEMER. Thank you, Dr. Guile.

Dr. Boulton, I would like to ask you an even more specific question after your testimony, too. You talked about many of the disincentives in terms of business practices that Dr. Guile and Mr. Elkus have pointed to as well, too. What types of incentives should we look to? Should the administration and Congress get involved in these kind of things? and what kind of policy options do we have to try to encourage incentives, whether they be investment tax credits, encouraging people in this country to save, where we save at one-quarter the rate of the Japanese and the Germans? Please talk about some of these bottlenecks that you specifically addressed in your testimony, and what we can do about them, and what types of incentives we should look to, if at all.

Dr. BOULTON. I'm not sure I have answers to all those questions, but—

Mr. ROEMER. That is why we invited you here today, Dr. Boulton. You are supposed to be the answer man.

Dr. BOULTON. Let me address one point with regard to capital. As we all know, capital is in relatively short supply not because it is inherently in short supply but it is in short supply for high risk investments. The area that we are talking about is relatively high risk investments, and so we don't have a good capital base. We basically rely upon the free enterprise system to provide capital for high risk ventures, and we call it venture capital.

Well, venture capitalists don't invest in high risk ventures, especially today. The industry is almost on its back right now, because they have tried that and they have failed.

We don't have a system whereby we can channel funds in any systematic way. Our banks primarily prefer to invest or to loan money to consumers through credit cards. I mean we all get probably five credit card applications a week. But if a corporation goes to try to get money from a bank, it is very hard to do that; we don't make funds readily available.

We passed some laws in the banking industry that we thought were good for banks which said that they couldn't be associated with corporations, that they couldn't have stock ownership and interlinkages. That is exactly what happened in Japan, is that the banks basically went into business with corporations for the long term and supported capital investments over the long term.

We need to think about how we can develop policies that are more long term in their investment approaches, and I think the banking system is one avenue that we need to do it. Our banks, I think, would have been better off investing money in our corpora-

tions than in S&L's, in housing. I mean, obviously, that hasn't worked. But that was basically the incentive system that we developed in this country, and we channeled an enormous amount of money into what basically, I think, were the wrong directions because—and this is an ideological problem that I pointed out earlier, is, our Government basically believes that we are involved in defense and we are sort of the area of last resort. We are involved in welfare and medicine, but we think that the free enterprise system should handle industry, and what we are finding is that that simply is untrue—you know, that there is a myth there.

In response to that, you know, the Japanese, we said they can't be involved in defense; we put it in their constitution, and of course we are talking about that today every day; and, at the same time, Japan really has not invested in the welfare system; they left that up to private enterprise; and the government in Japan basically is an economic-driven government role. And so what we have are basically incompatible government systems that can't compete. I mean we can compete in defense, but we can't compete in economic systems, because we don't believe that government should have a role in that.

Mr. ROEMER. Let me just ask you a follow-up question, too. Last week, somebody from CRS, Dick Nanto, who is an expert on this whole subject, talked about the families of businesses in Japan, where some utilize technologies, others develop technologies, and you many times have financial institutions within the company itself. Is this something that you—

Dr. BOULTON. Well, that is what I am talking about, is that each group in Japan, what they call a keiretsu, used to be—it is a spin-off of the old zaibatsu that we outlawed after the occupation. But the keiretsu—every keiretsu is centered with a major bank and other financial institutions—the insurance companies and what-not—to provide the capital for those groups and provided the capital early on. Today, those banks are losing their strength and power because the groups are so profitable, they are generating their own cash, they don't need the banks any more, so now the banks are going worldwide and they are moving around the world.

That is part of what I am talking about, is that you have in Japan a concept of business that we don't even have in this country. We don't have a concept—we can't even understand what a zaibatsu is or what a keiretsu is because there is no equivalent animal. We would inherently distrust it because it has potential power. You know, big is inherently bad in our country, and we depend upon this entrepreneurial spirit where we say everybody should have the right to go out and be successful.

The problem is that the kind of resources that Dick mentioned earlier, when you are talking about, you know, hundreds of millions of dollars in order to invest in a business area today, entrepreneurs can't do it any more. We are talking about stakes that are so high that our old traditional system is still fine for spawning but small companies, but don't try to do it in an area where you have got a keiretsu in Japan trying to compete against you, because there you have got—a keiretsu today probably averages sales—the total sales of a group is probably over $450 billion. We don't even have a competitive institution in this country today. The

biggest institution we ever had was AT&T, and it was our vision to break it up.

Mr. ROEMER. Mr. Elkus.

Mr. ELKUS. To follow on with that, I met last week—Tuesday of last week—with a friend of mine, Mr. Akiyama, who is president of Sumitomo Corporation. Sumitomo Corporation is the trade corporation part of the Sumitomo Group, which is a keiretsu. Sumitomo Corporation is $156 billion. To give you an idea of some of the concepts of that, it handles all of North America's distribution for Mazda automobiles. It is also the forty-seventh largest stockholder in Honda, and it is tied in with Sumitomo Bank, it is tied in with NEC, which is part of the Sumitomo Group; NEC is the largest merchant supplier of semiconductors in the world, to give you a sense of proportion and size.

The problem that we face is very, very difficult, and, I assure you, you will not overcome this problem with laws. There is no way. You can reduce capital gains to zero, and I think that would be terrific, but that will not solve this problem. I want to give you an example.

Several years ago, I had a company called Geometrics. We manufactured geophysical instrumentation. We got an order for $500,000 from a little company in Brazil. The company had lousy credit. That aside, at that point in time the cruzeiro, which was the currency then, was a soft currency and you could use it to paper your walls, it wasn't particularly attractive, but it certainly wasn't going to buy anything, and it was deflating—or inflating at the rate of 360 to 1,000 percent a year.

So I took the order and effectively put it in the circular file. I sent a note back and said, "If you want to send us an order based upon an irrevocable letter of credit in U.S. dollars in a U.S. bank, I'd be interested."

I got a call from a bank in the United States, and the bank said, "Would you mind if we act as intermediary and give you the money, assuming that you could pass our test as a qualified supplier, and whatever, to provide the equipment for this company?" I said, "Absolutely."

So we went to visit the offices of this bank, and they asked us all kinds of questions as to whether or not we were a viable company and what our financial background and our record and things of this sort, and we fortunately passed their test, and they handed us a check for $500,000, and a few weeks later we supplied the equipment, and everybody was happy, or so I thought.

In any case, when I walked out of the office of this banker with this check in my hand, I turned to one of my associates, and I said, "What in the world do they know that we don't know?" I mean I would never loan money to this company under any circumstance.

The bank was the Continental Illinois Bank, okay? This was 1977. Shortly thereafter, the Continental Illinois Bank started a run on our monetary system which could have broken the international monetary system, frightened the United States to death, the Federal Reserve stepped in and for the first time ever guaranteed every single loan of any consequence in that bank—everything, whether it was $100,000,000 or $100,000, because they didn't want to see the world go broke and the United States along with it.

Now the point I am making is this. The department that gave us that loan was the most profitable department in the bank, because they could get 15 percent when everybody else was getting 7.5. We are absolutely committed; our status in life, how we live, how we dress, how people view us is based upon dollars in our pocket today, but we absolutely do not understand a fundamental fact in the physical world, and that is that as you push products and markets to their logical extreme, they start becoming interconnected.

By the way, politics is an end use market, money is an end use market, automobiles are an end use market, VCR's are an end use market, microwave ovens are an end use market. All of those things are coming together. You notice that there's lots of talk about how much money countries are spending in the United States for lobbying and things of this sort. That is absolutely connected with what I am talking about.

If, in fact, you decide to make deals as your way of life as opposed to developing an integrated infrastructure, you will finally get destroyed, it is just the way things are, and the reason for that is that these individual products, as they fit together, create for the people who are pursuing that particular point of view, virtually a riskless society. Let me explain what I mean by that.

There is no master plan in Japan that says, "We are going to have this market and that market, and whatever, and this will be a success, and that will be a success." It is a win/win deal, not a win/lose deal; it is not a zero sum game. If, in fact, you really believe that products and markets are going to fit together as time goes on, then almost anything you do, as long as you stick with it long enough—and remember I said "in perpetuity" is long-term in Japan—as long as you stick with it long enough, finally it will be saved even though it was a very dumb move to begin with, because somewhere, something, some other part of the society will pick it up and utilize it. We can't conceive of that in our society. It is such a major change from how we live and how we do business that, literally, it is almost impossible for our academicians, let alone many of the people in corporations, to understand it.

I don't want to monopolize, but I want to give one last quick example.

Mr. ROEMER. Okay, and I just want to—I'll come back to you, too. I've got a couple of follow-up questions, and I know other members of the committee want to ask you some questions.

Mr. ELKUS. Okay. I want to give one quick example. I sat in a meeting put on by the Semiconductor Manufacturers Association, and an investment banker gave a speech to us, and that investment banker represented one of the venture capital investment banking firms of the west coast that is preeminent—I won't use the name—and they said, "Look, in your world of semiconductor manufacturing, you have got to recognize that you have niche businesses. The way to success for your companies is to find an area which is unique to you, where you can bring something to bear that gives you a reason for being that the other guy doesn't have. For that, you get margin, you get growth, and you get a hell of a price on your stock."

Now imagine this. In Japan, which today represents 50 percent of the total production of all semiconductor equipment, which is

fundamental to the semiconductor industry, which is fundamental to every electronic product in this world, which is fundamental to every market on this earth—okay?—three companies represent 40 percent of the total market in Japan, a country which is now spending twice as much on semiconductor equipment as the United States of America in absolute dollars, okay?

Those three companies are all billion-dollar ventures on their way to two, et cetera. There are 800 little companies in the United States, 75 percent of which are $25 million or less, and we are supposed to be finding our areas of niche businesses while the guts of the market go to three or four major companies in Japan and therefore our entire electronics industry. It is suicide for the country but great for a Dick Elkus or a Joe Smith or whatever else, who has a little company, who can sell his company, maybe to a Japanese firm or whatever, at a profit. I go home with money in my pocket; the United States goes broke.

Mr. ROEMER. Thank you, Mr. Elkus.

I just have one more question for Mr. Eldon, and then I'd like to get to Mr. Thornton.

We talked about education, and you hit the nail on the head a couple of different times, Mr. Eldon, on that. Two authors from the U.C. Berkeley Roundtable on International Economics have talked about manufacturing matters. They look at how high service jobs, value-added jobs in the service industry, are attracted by value-added jobs in manufacturing. What are some specific things that we need to do in apprenticeship programs, as you pointed out, in getting our businesses involved in occupational and technical education to keep our workers trained coming out of high school and keeping people trained as they are working in the work place as well, too?

Mr. ELDON. Of course, not being an educator, I don't have any complete answers to that, but I can tell you one or two things probably off the top of my head that are manifestly important to manufacturing operations.

One thing I have found over the last two or three decades is that people coming out of high schools, for example, are not knowledgeable at all about even some elements of basic arithmetic, let alone statistics, and that makes it very difficult to try to install in a manufacturing operation at the ground floor level, at the shop floor level, any knowledge of statistical quality control or any of the other techniques that are important to running an efficient manufacturing operation.

By contrast—and I made allusion to this—in Japan virtually every student who has gone through what we call 12 years of schooling, our high school level, is indeed able to understand charts and graphs and statistics as well as basic arithmetic.

Beyond that, in the time that—if you will allow a personal reference—at the time I went to school, learning the elements of engineering and science, I took a large number of courses and activities that involved using machines of one kind or another, and that is not so now. If you go to a high school now, almost everybody goes into a program that is aimed to put him or her into college to be almost an academician, but with social science emphasis almost exclusively, not only higher mathematics but no appreciation of

equipment or facilities or working together in teams to make things, and it seems to me that developing programs like that at the K through 12 level at least and to encourage more knowledge of, and understanding of, and use of equipment of all kinds at the undergraduate level in colleges is going to be undoubtedly an asset to our manufacturing operation.

Mr. ROEMER. Thank you, Mr. Eldon.

Mr. Gilchrest.

Mr. GILCHREST. Thank you, Mr. Chairman.

I came in here feeling pretty good today, but I guess this is a job that really needs to start now and our great, great grandchildren will benefit from it, so I hope the sense of the long-range planning which has no end to it will begin to filter into this institution, into this Nation, so we can begin to grasp this sense of future.

I read a book one time called "The Ascent of Man" by Jacob Bronowsky, which is a book kind of describing the evolution of science, and one statement kind of stuck to me about human evolution, and he said that the hand is the force which drives the subsequent evolution of the brain, and when you talk about markets, which is a leading edge for what technologies will result from it, I guess that's a concept we need to grasp.

I have a few questions which anybody can answer, I suppose, and we are talking about this integration of systems, this integration philosophy which doesn't seem to lend itself too well to the United States, but certainly it does to Japan, for a variety of reasons, I suppose: They are more cohesive and unique in their culture as opposed to the diversity that we see here in the U.S. They are a fairly small unit that function, traditionally and historically, in one direction. The family, the community, the business, all are related. It is like an extended family concept that they have in Japan that we lost here some time ago, but I think we used to have it here. We used to have what works, we ought to go with it, and now we are separated into units of who can make the most money, and you said our long-range planning was 10 years; I think sometimes it is 10 minutes.

But looking at it from a practical sense and how we can get into that mode, the Aegis system for the Navy, I think, picked up the concept of integration in a long-range perspective, and maybe we need to study, I suppose, that kind of system. Maybe it could be used, in part, as an example to get us into the philosophy of integration.

Dr. BOULTON. Yes. Let me comment briefly on one piece of what you are talking about. I think one of the things that concerns me is that we really tend to deal with problems specifically. We take a problem, we try to identify it, and delve into that specific problem, and come up with an answer to that little piece without ever looking at the consequences of it, and when you start thinking about systems, then you start looking at down the chain from that particular problem to the next stage, to the next stage, to the next stage.

So while integration is one part of it, the issue that I addressed is the systems concept. Let me give an example. You talked about the Technology Transfer Act. We passed it in good spirit. I mean we are trying to open up the labs to get the technology out because we

are investing now this—the budget this year is looking at $74 billion for total R&D in the United States, and we are saying, well, we ought to open that up so at least we can commercialize, get some of that technology out. So we passed the laws.

In those laws, we said somebody has to be responsible for technology transfer. We did not even think about putting money in for education, to tell those people or to develop and understand what technology transfer means, what those managers' responsibilities should, in fact, be. We left education totally out of the equation, because the point about education is, we have lost the vision of education in this country, we don't believe in learning any more, and I don't know where that came about.

We have become a credentialist society. When somebody graduates from high school, what they have to do is have a high school degree to get a job. Nobody ever asks them if they are literate. I'll bet 50 percent of our high school graduates cannot read or do math at the eighth grade level, and yet they can get a degree and walk out on the street, and all that is important is that they have the degree. Nobody ever asks you if you learned something as a result of that credential. As a result, we have lost the content of our school systems. That is why we don't teach math.

The National Science Center Foundation down in Augusta, Georgia, that Dr. Davison is the president of, is developing a new technology to teach math in high school, from algebra through calculus, and he is up here battling to try to get money to fund that activity. They developed a new software, and it's in prototype stage right now in Georgia, and the results are phenomenal, but he's banging on walls, trying to get somebody to see the vision that we can't do it through our traditional education approaches. We are going to have to apply technology to help in the learning process. We still don't believe in learning.

When I was in Japan last time, I was amazed. I went around to all these exhibitions. In Japan, there are over 120 worldwide exhibitions. They bring products in from around the world on every major industry every year, and I went around to these exhibitions, and I mean I was in line for two and a half hours to get in these things on robotics and factory automation—that is not a sexy topic—and I had to wait to get in these places, and I started asking the question, "Who are all these people?" and the answer was, "It's everybody; these are students, these are engineers, these are managers." I said, "Well, what are they doing here?" They said, "Well, they just want to find out what's new, because it might be of some use to them."

Now you ask your colleagues when the last time they went to an exhibition was. We just don't—we don't do that, it's not what drives us, and I don't know where we lost it, but it's an ethical problem in learning, and it's my concern, in the Technology Transfer Act, is, we've opened the doors of this $74 billion sitting out there that we put in R&D, and we didn't consider the next stage in this process which was, "How are you going to get it out?"

I estimate there are probably 350 labs that are really significant out there, and they are probably going to produce, on the average 50 new patents a year. Did anybody think what that is going to cost? If it costs you $50,000 per patent to get it patented worldwide

to get protection, and you multiply that times 50 patents, times 350, do you realize, we are talking about another billion dollars in expenses and absolutely no revenue generation out of that in the short term?

We have got a crisis in the making because we never considered the next stage, which is why—how do we determine what the market feasibility for those technologies are, and how do we get access to people that might want to use them so we can get them into the marketplace, so we can generate some revenue to cover our legal fees just in patenting alone? It's this problem of addressing a problem and not looking at the system, and that's why I mentioned systems approach.

Mr. ROEMER. Dr. Boulton, you are talking to a former teacher, so I think your education comments are hitting upon sympathetic ears over there.

Mr. GILCHREST. They are, and I understand the need for K through 12 in the public school systems to be revamped and revitalized and changed from the ground up. That can be done within the school system, within the community, without new buildings, without a whole lot of changes, just targeting certain specific colleges and businesses to help with the local schools.

Dr. BOULTON. Well, there's two. One, I think that our approach to maybe setting some national standards that we can measure what is happening in the schools is going to back to content and saying, "Look, people really have to learn something as a result of going to school." I think that is maybe one approach. I am not sure I really like that, but at least that is a first step to begin to put content back in the school system.

What I am worried about, further than that, is what is happening right now to the universities. You know, we have got 27 States that are dying budget-wise, and they are taking their money right out of education, because education is not a high priority item, and I'm afraid that the decline of universities right now is—you are seeing the beginning of the end. What happened to K through 12 is being effected by universities because our States aren't investing today in education. They are taking it right out of education because their budgets are in a crunch.

Mr. GILCHREST. When we look at this problem in its completeness—at least I do—I'm not sure if we can ever compete with Japan on a level playing field because of the differences between the two countries, and I hope we don't think that we are going to have to begin mimicking what they do. I don't think we can. Their country is much smaller, their culture is so much different, we are so much larger and more complex and diverse, and our philosophies are different, so I hope we don't adapt the philosophy that we have to mimic what the Japanese are doing, because I don't think we can—I'm not sure if we could do that in the same way.

Mr. ELKUS. I want to ask a question of you.

Mr. GILCHREST. Yes.

Mr. ELKUS. What do you mean by "mimic"?

Mr. GILCHREST. What I am hearing this morning is that the Japanese have—you were talking about the shows that are put on for various new technologies and techniques and people come and

watch them. Geographically, it's a little bit easier for them to do that than it is—

Mr. ELKUS. But we have those kinds of shows here all the time.

Dr. BOULTON. They are everywhere. All I'm saying is that they are—that is part of the national strategy in Japan, to make sure that people—and people go and see them in droves. We do it in computers. We have our national computer shows and what-not very well attended but not by the same breadth of society.

Mr. GILCHREST. Maybe the reason it is so successful—I don't want to diminish the fact that they are important or diminish the fact that we need to begin integrating the VCR's with the microwave ovens and the automobiles. I think we need to do that as well and think that way for the future.

However, adapting that to our culture is the difficult part.

Dr. BOULTON. Okay. Let me just make one point here. Let me come back to the point that I made. I am talking about systems. What we have—in our system, we have bottlenecks or we have vacuums that aren't being addressed. If you are talking about getting quicker to the marketplace, then we have got to build a system that is competitive.

I am not talking about necessarily replicating the Japanese system, I am saying that we have to build a system. Our system will be uniquely adapted to our requirements and our constraints, but we have got to look at it from a systematic point of view as to how we can overcome these barriers.

Mr. GILCHREST. If this then is going to—and I think you said we were not going to pass laws, but it is going to have to be, I would think, some type of joint private/government venture. What is going to be targeted?

Mr. ELKUS. There isn't enough money in the United States Government to resurrect the kind of system that allows us to be competitive in the United States. The answer is not going to be in money from the Government of the United States; there just isn't enough around.

There are many ways of doing it. The first thing you have to do is, we have to cut out this idea that we can walk away from products and markets because we can't make enough money relative to some place else. That is the first thing you have got to start doing.

The second thing you may have to do is, you may have to start developing some joint ventures with companies that are in the business, as Japan did at the end of World War II, and say, look, if you want to have some participation in this marketplace, and there are a lot of ways of doing this, but we would like to suggest that you set up a joint venture with such-and-such company in the United States, 60/40 U.S., with manufacturing, research, and development, or whatever, in the United States, so we begin to redevelop an infrastructure rather than try to do the whole thing all by ourselves, okay? It requires a mind set.

Let me answer why it happened in the first place. In Japan, there are no natural resources. There is this little itty-bitty island in the middle of nowhere, okay? and everybody recognized that they either hung together or they died separately.

In the United States, we had every resource known to man, and, not only that, but we were totally self-sufficient in terms of our

own market. We didn't need for years and years and years—up until maybe 1970, we didn't really care about what happened in the rest of the world; we could survive here literally with our own food, the production of everything we had to made; we never had to trade with anybody. This was not a luxury that Japan had. Consequently, if somebody in San Francisco decided they didn't like being in a business, they could get out of it, went to North Carolina, or went to New York, or went some place else, but it stayed in the continental United States, and then somebody got the idea that our labor costs here were just too high relative to Singapore, and Thailand, and Japan, and Korea, and elsewhere, and we started sending stuff offshore, and we found that the people could produce our products better than we could and we could somehow take those components and make an end use product out of it that gave us the money in the short term.

Then, all of a sudden, we found out that the margin between what we were paying for these components and what we could sell it for in the marketplace was getting pretty tight, because the prices were coming up on the stuff that our so-called offshore suppliers were charging us.

We also began to recognize that they, our offshore competitors, were coming in with end use products of their own which they were competing with ours, and then their prices were not necessarily as high as ours, so we had to drop ours, the margins got too tight, and we went out of the business. That is what happened to television, that is what happened to audio recorders, that is what happened to video recorders, that has happened with most of the consumer electronics industry.

Now let me come at it from a different standpoint. You talk about commercialization and getting technology out of our laboratories in space. That is a lousy way of getting technology into a commercial product. The best way to a commercial product is through the consumer electronics industry, not the other way around. Think about it. It is very obvious. What is a consumer product that is perfect? It is extremely reliable. I mean anybody can take it and beat the hell out of it and it is going to operate. It doesn't require lots of spare parts. Its mean time between failure is forever. Its cost is very low. Its distribution is everywhere. Its service is very low, but it is easy in access to get to. It is very easy to understand for anybody to operate it. It is small, portable, miniature. You can carry it every place. That is a consumer product. That is the best in commercial products.

We only went for commercial products because there was greater margin, because there was a smaller market, and somehow you could develop this so-called technological expertise that gave you a higher percentage because you were somehow unique from that technology. That lasted for 15 minutes. That is what is happening to everything.

When we did our study in Japan for high definition products and systems, one of the fellows on the committee who is head of the Society for Information Displays came up with a conclusion, and wrote me a letter to this effect, that what he saw on the consumer shelves in Japan in electronics packaging and display technology was better than anything he knew existed in the DOD.

The point I am making is, there isn't an easy way. We are not here to mimic the Japanese. The one thing we can do that almost no other nation on this earth can do is, we can change our culture because of a book, because of an idea, because of the respect for the individual and the respect for ideas which allows us to compete and utilize people from all over the world better than anybody else. But we have to escape one fundamental thought, which I think we can, and that is, just getting it all now is very destructive in the long term, and the long term finally shows up.

Mr. GILCHREST. That is a mind set that I would totally agree with you on, and I hope that mind set filters into—I think it would filter into the American public before it filters into the political system. The political system operates on very short cycles, and that mind set has to change. So thank you for your testimony.

I had a few more questions, but I would like to continue to communicate with you, and I'll do my part, as I think everybody else on the panel, or on the committee, will do to somehow begin to change that mind set.

One very short story, and I don't want to take up too much time, but I remember my grandfather, who was a teenager in the 1890's, would tell me what life was like in the 1890's, and I try to convey that to the people that I meet in this political world, that the decisions they made in the 1890's have a direct bearing on us in the 1990's, only the decisions we make in the 1990's will have a much greater impact on the people that will be alive in the 2090's. So I hope we take your advice and apply it to the areas that it needs to be applied to.

Thank you very much.

Mr. ROEMER. Thank you, Mr. Gilchrest.

Mr. Thornton.

Mr. THORNTON. Thank you, Mr. Chairman.

This has been a fine panel. We have discussed the problems; we know where we are. We have also had from each witness suggestions of things that should be done. I would like for us to pursue the direction that we should be taking in the future.

I am deeply concerned about where we are. I think that, as Dick Elkus has indicated, part of the problem is cultural, that we have a mind set for the short term. I think that, as Bruce has suggested, the prepared mind—Louis Pasteur—I was pleased to see the quotation from Louis Pasteur in your prepared remarks about, "Fortune comes to a prepared mind," and that our expectations, that a flash of brilliance followed by dogged application will result in achievement, and questioning whether that is, in fact, working.

Dr. Boulton, with his splendid suggestion of the need to stimulate demands by providing incentives to eliminate bottlenecks.

A concern that we don't have an organization, or structure, or process to assess technologies, and my concern there—and when we come back to it I would like to ask you to comment on it—is that that is what I thought we were doing a few years ago when we created the Office of Technology Assessment for the Congress, and perhaps we need to provide some additional charges to that organization.

Mr. Eldon's splendid testimony.

One of the things that concerned me was whether, indeed, the best thing to do with regard to educational programs was to charge overseas users of our educational system a complete fee, and I would like to have you comment on this, but in context with an idea that seems to me to have some merit, that we ought to have a national scholars program for American citizens.

At the University of Arkansas, we put in a program called Sturgis, scholarship which pays each academic scholar about $30,000 a year—all books, all fees, living expenses, and spending money. It may be a surprise that we recruit students away from Yale and Harvard on this program and that it is being expanded by people because it provides a stimulus not only to those students but to a lot of others who want to participate in the honors program.

Can you imagine what would happen if this Nation had a premier scholarship program so high school graduates who qualified intellectually for it could get that kind of return for their years?

Go ahead, Mr. Eldon.

Mr. ELDON. That would be almost as good as the remuneration to the football players that—

Mr. THORNTON. In fact, it was better. It was designed to be better.

Mr. ELDON. Or the University of Nevada at Las Vegas basketball team.

But yes, I think that would be a magnificent kind of thing.

If you like quotations, there is one from Thomas Carlyle which you might remember: "Show me the man you honor, and I will know what manner of man you are."

Mr. THORNTON. Hear, hear.

Mr. ELDON. If we can honor, I think, outstanding students anywhere approaching the way we have honored financially and by attention in the press the people who are good in athletic of one kind--of a few kinds, at least, I think we could make big progress. I think, yes, it is a cultural thing, and the systems of reward that we have in our culture are different from the systems of reward in other cultures, but I agree completely with Dick Elkus when he says enthusiastically that we have a country here and a culture that can change, and not everybody else does, so it is up to us, you, the leaders of our country, to set the stage and set the direction that can lead to the changes that we need in our society, I think.

Mr. THORNTON. I would like to ask you further to comment on whether that kind of impact upon our educational system would necessarily be long term in effect. I do believe that we need to have a longer view and that we need to be concerned about where we will be at the beginning of the twenty-first century as a competitive nation and that we should be doing things now to assure that we will be well placed at that time.

But could not the kind of dramatic shift in priority, reordering our priorities toward education, have a more significant effect even in the short term?

Mr. ELDON. I think it could have a significant effect short term or intermediate for a few years. I am less sanguine, I have to admit, about the long term by comparison. Let me explain that.

Mr. THORNTON. Okay.

Mr. ELDON. I had the opportunity to travel in the People's Republic of China and in Japan a number of times, and I have had the perception over the years, having grown up in the Hawaian islands with those people, that the culture of those societies is such that throughout as much as we have of recorded history they have almost worshiped learning. That is not the culture of a number of the people who have come to this country, and therefore I don't know.

But we do have here the opportunity for people from those societies, all societies, to come here, and I am encouraged to find that, for instance, when you look at the students who are the outstanding students right now coming out of high schools, for example, and the kids who win the math awards this year are named Minh, like M-I-N-H, and Wong, and Yashimoto, and names like that, and I think maybe if that kind of attitude, which comes surely from their families, can be made public and rewarded the way you are suggesting, that other children growing up will look and see, oh, that's what it takes to get attention, that's what it takes to get ahead, and that it will rub off. So maybe it would work long term.

Mr. THORNTON. Well, the process of education comes from the word "educe," or to pull through, or to stimulate, or to motivate and to grow, and it seems to me that what we are talking about, in part, is a process or a strategy of motivating people to achieve.

Dr. Boulton?

Dr. BOULTON. You see, one of the concerns I have: I have two boys of my own that have gone through this system, so I am fairly close to it, and I have been especially concerned that I think our education system has refocused its target to be the average. We basically—we have so many problems on the low side with illiteracy that most of the administration's time gets locked up dealing with the problem children. They make an assumption that the best and the brightest will take care of themselves, but they put all kinds of bottlenecks in the way, and they don't allow them to progress at their own level of ability, and so, what we—and it comes out of, I think, our early efforts at EEOC and equal everything, and, in terms of result, when we tried to integrate our schools, we did all these things, and one of the things we sort of gave up was this concept of excellence in the school system.

In fact, we go so far as to pass Federal laws that students can't take elite courses, special courses, more than like two or something at a time when they are the best and brightest. The rest of them have to be mainstream courses.

So what we have done is, we don't believe in elitism, and what you are professing here is that we build an incentive to find out who our best and our brightest are, and that would basically go against the whole legal structure we have set up for our school systems.

So we have got to begin to understand that the future is going to be dependent upon our best and our brightest, and we have got to begin to rechannel those folks, and find out who they are, and encourage them, instead of losing them along the way. You know, we lose them down there in the fifth and sixth grades.

Mr. THORNTON. I am not sure if there is an inevitable conflict between providing an excellence of education for the best and bright-

est and having in the same classroom people of abilities less than that who are stimulated by the classroom operation to achieve if you motivate.

Dr. BOULTON. Yes. I took my eldest son out of school two years early. He will never be a high school graduate. He is at the university instead because, for him, there was no challenge, and we have to open those kinds of opportunities, let people go at their level of progress, and encourage that, and build motivation in systems to allow that to happen.

Mr. THORNTON. I would like to change the direction of the questioning just a bit before we go to the other two panelists. It seems to me that consistent through everyone's testimony has been the need for a process, the need for a cultural change, the need to make a significant adjustment from the ad hoc solutions to specific problems that we have experienced in the past, waiting for the flash of brilliance to dominate a field.

I agree with Dick Elkus that the marketplace is the powerful instrument in driving productivity more than the flash of genius that invents something and somebody else smart sits around and tries to figure what good use can be made of that invention, and it seems to me that what we are really searching for in this country is a process, an analysis, a comprehensive approach to developing for America not a Japanese system but a system that is tuned to our own country's resources and capabilities. We are not a resources poor country, we are not a human poor country, but what we have been lacking is an idea, a concept, a way of putting it together, and I have used—and Chairman Roemer is probably going to get tired of this, but I have used the example of our assistance to Europe following World War II.

In the first two and a half years following World War II, we spent in humanitarian aid, relief, potatoes, $11 billion, at a time when this country had a national debt much worse compared to its GNP than we have two, 2 percent of our gross national product. It did nothing; it was throwing money at the problem.

After two and a half years—in fact, a little before that time—George C. Marshall said, "Why don't we do this in a comprehensive, careful way? Why don't we stimulate the European economy to recover? Why don't we concentrate on manufacturing capability, on agriculture, on a sound financial basis, on education of young people? Why don't we give them a sense that they can attain and achieve, and why don't we do that after carefully studying this not only among ourselves and the Congress and the Presidency but with the people who are involved? Why don't we pull in industrial leaders from Europe and find out what they need in order to make this change?" And so the Marshall Plan spent $13 billion in the next three and a half years, less on an annual basis than the uncoordinated and ineffective pouring out of money in the first two and a half years, and the transformation was remarkable, and that is why I have been calling for a Marshall Plan for America, not the Marshall Plan but that same kind of systematic—Dick, do you want to comment?

Mr. ELKUS. Yes. I think, though, there is something very implicit in what you are saying, and that is that you have to have leadership to do that.

Mr. THORNTON. And vision.

Mr. ELKUS. You have to have leadership and vision, and it has got to come from the executive branch.

Mr. THORNTON. Well, I'm not sure.

Mr. ELKUS. The reason I say that is that all of us can talk about it, but it is hard for individuals to separate themselves from the system that is asking this of them and that of them which may be in opposition to where the Nation as a whole should go if the top guy doesn't somehow indicate that he has a similar type of vision.

Mr. THORNTON. Well, there are some suggestions that within the administration there are those people who share this need for a vision and for a systematic approach and we need to capitalize on that, but let me say that what I am hearing in my own district, is that the real top man in America—that is, the people—are wanting this kind of leadership, they are wanting this kind of vision. They recognize, maybe ahead of the Congress, the situation that we have fallen into, and they are looking for a strategy to pull us through it, and that is the top person, and I believe if that top person gets this idea and goes forward with it, then everybody will jump in on it. How do you feel about that?

Mr. ELKUS. I basically agree with you, but I would like to suggest something.

Mr. THORNTON. Okay.

Mr. ELKUS. There is an article sitting to your left, written in Fortune magazine, okay? And in that article, it talks about this thought that is floating around in Japan which says, you know, "Who are you guys anyway? We are loaning you money so that you can go deeper into debt to afford a standard of living three times ours." Okay?

Mr. THORNTON. Yes.

Mr. ELKUS. Now, the point I want to make there is that it is all of us that are borrowing that money in our credit cards, and however else you want to look at it, to have the good life.

Mr. THORNTON. Absolutely.

Mr. ELKUS. So it does require some conscience somewhere to say to you, "Hey, wait a minute. Maybe we had better slow this thing down and think about what happens over the next 20 years or 50 years, not what happens over the next 15 minutes."

Mr. THORNTON. I agree completely. I think one of the greatest problems we have is our emphasis upon short-term goals rather than looking ahead to what we need to become. But a strategy can begin to affect us as of today.

Dr. Boulton, you also were indicating your wish to address this issue.

Dr. BOULTON. When we talk about incentives and your concern about letting the populace basically provide a leadership, I'm not sure that that can happen, you know. I have never seen an organization of any kind where the masses can find direction in and of themselves. As we know, it is a political process then, the old rule of 51. But you have to have somebody who has got the vision. You know, the whole population is not going to have the vision; they are going to follow a good visionary, because they will provide the vision for the population. And so I come back and I say, "Look, we need some very strong leadership that has a vision of the future

and that can communicate that vision effectively, and those people will then follow; they will support that vision. But you can't go down there and ask them to create the vision."

Mr. THORNTON. I agree with that, Dr. Boulton.

Mr. ELKUS. Like George C. Marshall.

Mr. ROEMER. And I would just like to comment for one second in support of my colleague's comments. If you would notice from the panel, our committee makeup comprised today four out of the five people were freshmen, and the leadership spends about the first week with us when we get here because we are hot off the campaign trail, having spent 15 months there listening to people, and I couldn't agree more with my colleague from Arkansas.

It is the same in Indiana. People are concerned about their jobs, trade with the Japanese, education for their kids, a decent manufacturing job and wage to live on, and we need to see some leadership.

I sit up here and go back and forth from the Education Committee to the Science, Space, and Technology Committee. I hear it from CEO's at Honeywell and IBM that are complaining about jobs and the education system where we are producing not enough of the gifted children that graduate or don't graduate from high school but that 40 percent of these kids get to the door and are at risk before they walk in the kindergarten classroom, and now businesses are saying, you know, this is the rule rather than the exception. These kids are dropping out of school, and we are building prisons faster than we are schools.

So it all comes back to this idea, I think, that I support my colleague on, and the vision and leadership has to come from Congress, it has to come from the President, hopefully, and the administration, it has to come from people like you, and we need it. We are in desperate need of vision and leadership in this area.

Mr. THORNTON. Go ahead.

Mr. ELKUS. I would like to point out, in case you aren't aware of it yet, that the engineering societies, of which IEEE is one—it is the biggest, but it is only one—have started a program just this last year of recruiting 100,000 engineers throughout the country, representing in the case of IEEE every single place where we have an association branch, to be consultants, guides, assisters, at the local school level, to teach—to help teach some manual arts kinds of things that are involved with engineering, like how you build buildings and houses and so on as well as electronic equipment, but also to teach math, which we just have to know something about, and it seems to me that kind of attitude, if we could extend it to other professions, would be somewhat helpful. It is a lot of people; they have an influence.

Mr. THORNTON. Thank you, Dr. Eldon.

Let me come back to a question about whether leadership necessarily has to come from the executive. Certainly for something to work well, it must be agreed upon and implemented by both the executive branch and the Congressional branch. However, let me make the observation that in the spring of 1973 a Congressman from Washington State named Mike McCormick and I sat down and drew up the first legislation to establish an energy policy for

this country. It was before the executive branch had any idea that we needed an energy policy.

We came up with bills to provide for a more fuel-efficient automobile, for solar heating and cooling, for geothermal and shale oil. These were introduced in the spring of 1973. Everybody just kind of snickered because we were awash in a sea of cheap oil. However—and even as a representative of a 24-county rural district that had no public transportation, I came out in favor of subsidies for urban mass transportation because of the energy consequences. The Washington Post put me on the op-ed with the thing.

Okay. The bottom line is, in October the Arab oil embargo convinced people that there might be an energy problem, and so out of the congressional initiative came the foundation of a national energy policy, which was picked up by the Ford and the Carter administrations, and then all exporting countries lowered the price of oil and we went back to a different energy policy, which I think is a very detrimental energy—but the point is, the point is, that indeed vision and leadership often come from the science committee at least. George Brown is a visionary. He is a person who can really do an outstanding job of taking an idea and moving it forward. So I think we just need to stimulate this thing.

Are you nodding?

Mr. ELKUS. I agree completely. I mean everything that you have said—I know George Brown very well. I think the world of this man. I think he is a visionary, just as you have indicated.

Mr. THORNTON. Yes, indeed.

Mr. ELKUS. I also think that the Congress can make a tremendous effect on this country, but I think there is a guy in the White House, and I have tremendous respect for that man, but his Council of Economic Advisors, or whatever, that have to somehow get on this bandwagon too.

Mr. THORNTON. I think we have got some work to do, but I think it is attainable, and I think the task is worthy of all of our efforts in doing so.

Doctor?

Dr. GUILE. Just one quick comment with regard to the leadership issue. I think that in talking about the degree to which markets pull on technology, I agree completely, and I think it is a very powerful argument and one that needs to be integrated into thinking about it—how often the science and tech side of the national institutions tends to push on research, or push on science, or push engineering out.

If you start thinking about the degree to which markets pull, you start leading yourself inexorably down a road of thinking about national sovereignty over the markets we do control, which is essentially consumption in the United States, and it gets dangerously close very quickly to thinking very hard about trade protectionism, protecting infant industries, allowing the integration of markets to happen in the United States, and I think that the primary challenge in terms of leadership and vision is to come up with some sensible way, without shooting ourselves in the foot, to integrate the way we think about international issues like trade policy with investments in technology in this country.

I think that the days when we could regard ourselves as an isolated entity and invest in this country and assume that everything that happened was good for ourselves only, or if it spilled over we didn't care, are gone, and we have to be more intelligent about managing our technical resources in the context of global competitors, and that may mean dealing effectively with trade questions in a way that we haven't before.

Mr. THORNTON. Mr. Chairman, if I might conclude with just the observation that, lest there be any mistake, I am not suggesting that this is a planning effort in which the Government should become the principal actor. I am suggesting that it is a strategy, that it is a process, in which the role of Government should be to seek to gain information from the different sectors and to stimulate the kind of development that we are calling for.

Dr. Boulton.

Dr. BOULTON. There is nothing wrong with the Government providing the coordinating mechanism.

Mr. THORNTON. Absolutely.

Dr. BOULTON. I mean you can get all the right people together. It is very hard for a non-government agency to get presidents from major corporations to sit down and talk about specific areas that need attention.

Mr. THORNTON. That is right.

Dr. BOULTON. And the problem is, we have really sort of disconnected between what the role of Government might be in that sense when, in fact, there is nobody else with equal power to bring those kinds of agents together to talk about some of these problems and to begin to develop the strategies, because they have to implement them, and, if they are not a party to them, then they are not going to be effective strategies.

Mr. THORNTON. Harkening back to the Marshall Plan for one moment, in Europe the interesting thing is that, after pouring out $11 billion in an uncoordinated effort, the program went forward to develop strategies to accent the development of entrepreneurial and growth on the part of each of the entities under the fabric of a systematic approach to stimulate economic recovery. The interesting thing is that it began to work before the first dollar flowed. It wasn't just the $13 billion, 2 percent of GNP, it was the process itself that began to turn things around.

I yield back the balance of my time.

Mr. ROEMER. Whatever is left.

I would just like to make a comment and then maybe one final question. I think, as Mr. Thornton said, and as many of you agree on the distinguished panel today, I was at the White House a few short weeks ago when the President outlined his proposal on education, and I am willing to work and cooperate in a bipartisan manner with the President on a number of those proposals. I think we need to look at innovation and we need to look at creativity and we need to unshackle some of the bureaucratic handcuffs in the schools. I think that is all Mr. Thornton and I are saying in this case and with hearings, is that we need to get attention on this matter and that we want to work with the White House in this kind of a bipartisan endeavor.

Mr. BOULTON. And some of those things are going to take dismantling of laws that are in place now because they are dysfunctional.

Mr. ROEMER. Well, let's maybe talk about that for a brief moment here and then conclude.

Mr. Elkus, you said in your comments—you emphasized that technology follows markets. I think we all think that, you know, the private enterprise system, along with maybe some help from the Government in some strategic areas, but the private sector and entrepreneurship is the best way to go.

What kind of evolutionary, rather than revolutionary, processes are you referring to, and where can the Government specifically help in that process? Is it in the process of, as we have heard testimony from improving the manufacturing line in incremental ways, as the Japanese have done? What are some very specific things, whether it is monetary policy, management/labor relations? What are some of these evolutionary changes, Mr. Elkus, that you are specifically focusing on that we can help and that the White House can help on?

Mr. ELKUS. The first thing I would do is, below the President—I think from my standpoint, the first thing is that the President and his Council of Economic Advisors has to be convinced that what we are talking about here makes some sense.

But I would set up a committee called Office of Strategic Analysis, for lack of a better word, reporting within the Department of Commerce, for example, with direct ties to OSTP, and it would include a series of very expert individuals that understand products and markets and begin to try to assess what areas, as we have done already in the private sector in certain reports that have come out—plus, by the way, the thing I referred to in the Department of Commerce report on strategic technologies, what particular products and markets seem to be more strategic than others as the future develops.

Mr. ROEMER. Can you refer to a couple? Are we talking about telecommunications, industrial ceramics, high definition television?

Mr. ELKUS. Well, let me take high definition television for just one second. All high definition—forget the word "TV." All "high definition" means is the ability to process on a relative basis lots more information than was processed in the past. By processing more and more information—and this is the reason why it is so important in Japan—the Japanese feel that there are three basic end use markets: media, including mass media, software generally; telecommunications; and electronics are going to become one basic market, totally integrated. They will be integrated as you process more and more information.

You can obviously see that a CD, a compact disc, has more information than a 33 r.p.m. record. The result is that you can do certain things with the music world you didn't do before. Now you add pictures to that, flat screen displays, a whole bunch of other things, and you begin to collect a whole other set of products and markets together.

The reason why Sony bought Columbia Pictures and CBS Records was not to make a capital gain on those two areas of activity but to integrate the software and the hardware. I talked to

Morita about this at length, and he states it not only verbally but in his annual report and all kinds of other documents.

In any case, I believe that in answer specifically to your question of what areas, the area of telecommunications, electronics including computers, and the media are absolutely areas of criticality. In other words, the ability to flow, control, distribute, handle, process information is going to be essential, not only to those particular markets but to all other markets.

Once you determine that, then I think a dialogue with industry across the board—and, by across the board, I mean in every sector of our country—we have to begin to have a dialogue that states or that addresses the problem, what are impediments to our abilities to succeed in those areas? Are there products and markets that we don't participate in which, in fact, we should participate in if, in fact, the products that we have today will be successful long term?

Once having achieved some level of consensus in that dialogue, then you can begin to think about, and only then, you can begin to think about what types of changes in rules, mores, taboos, and whatever, can be established to allow us to more freely exercise an economic or industrial base within our country to be competitive.

So, for example, we may want to ultimately ease our antitrust laws so that you can begin to cooperate in end use products, not just in research and development or certain manufacturing techniques, as is the limitation to Sematech. You may want to change capital gains and structure things so that as long as you stick with it for a period of time you get certain tax breaks as an incentive.

But the primary thing is to determine how do we get back into businesses. You may want to establish certain types of relationships which allow us to use our current markets to entice foreign competitors to do joint ventures in the United States to our advantage, and, by the way, I think there are foreign competitors, for example, in Japan who are very willing and interested in talking about those kinds of relationships, namely because they have done it before, themselves, and they understand the logic of it.

The most important thing is that we have to begin to recognize, as Congressman Thornton so aptly said, that strategically we have to begin to have a strategy, a national strategy: What, as a nation, are we trying to accomplish? What do we expect of ourselves? And what are the ingredients of an economic society that are essential to achieving those goals?

Once you have that strategy, which I believe is a part and parcel of this Office of Strategic Analysis, then you can begin, and only then, you can begin to have a coercive set of laws or lack thereof, regulation or lack thereof, to ensure that you have a cohesive society to address those strategic problems.

Mr. ROEMER. Dr. Boulton.

Dr. BOULTON. Let me just follow on. Once you have identified your strategic areas, you see, then we can come back and we can ask the question, what is our current data base in terms of technologies, and what is going on in our labs, and what do we have in terms of capability that we can apply to the problem?

But, you see, the problem is, we don't have a vision, we don't know what it is we are supposed to target, and, secondly, even if we did, we don't have any methodology by bringing quickly in any

systematic way the capabilities we currently have, the experts down in those labs across the Nation, that we can bring to the problem in some coordinated fashion to take action, and so we are lacking on both sides. We haven't identified what is important to us or what is important to the future, and, even if we did, there would be no way for us to bring to bear our resources in any rapid manner.

Mr. ROEMER. So you are both talking about in education and a strategy as well, too, as you mentioned before.

Mr. ELKUS. Let me give you one specific thing that was brought up really early by Mr. Eldon, and that is that there was an urging that we should have a high definition television standard, some standard that we can identify, that we can operate to within the country. Think about that. Who is going to supply all the equipment? Who is going to supply all of the fundamental software and gear, et cetera, necessary to take advantage of that standard?

When we were in Japan, there wasn't one company there, from the president on down, that didn't urge the following thing: "We don't care what standards you adopt, Japanese or otherwise; frankly, we're not so happy with our own standard; it's forced on us by NHK. Just adopt a standard. Within a year, we'll provide all the equipment you need."

So what we don't want to do, or do want to do on a more positive basis is, we want to make sure that we are not just developing highways for somebody else's product. We want to develop an infrastructure that takes advantage of the standard that we establish. To do that, you have to have a strategy. It is too big. The ultimate efforts required to build high definition systems and products across the board will amount to a trillion dollars. You are talking big bucks. It requires a national strategy.

Mr. ROEMER. Mr. Eldon.

Mr. ELDON. At the risk of saying IEEE too many times, I want you to be informed that, picking up on Mr. Elkus's recommendation that there be started in the Department of Commerce some research forward planning activity, I took some unilateral action a year ago and contacted Tom Murren who was, at that time, assistant secretary of commerce, and who I had known through business associations to be interested in U.S. competitiveness, and I said, "What can the IEEE do to help you?" And he said, "Give us some people who know how to do advance planning and analysis of technologies that are required," and so I got a lot of lawyers involved, and it took time to get an agreement worked out, but last month I presented to the Department of Commerce, to Bob White's department, two gentlemen who I know, by having talked to them a lot—I've worked with one of them for 20 years—two people who are going to be able to do just that sort of thing. One of them is a former assistant director of R&D for Itty-Bitty Machine Company—IBM. The other is a former strategic planner in the materials area from Hewlett-Packard Company. Their abilities overlap. I think they will be able to offer enormous help to the Department of Commerce and, I hope, to you people, too, in identifying just the sort of thing that Dick Elkus was mentioning.

Mr. THORNTON. Mr. Chairman, may I just mention that on hearing Bob White's testimony before this subcommittee some time ago,

I became persuaded that there needed to be an additional amount of money in the Department of Commerce at that level in order to accomplish just the kind of planning that is being talked about here today, and I am pleased to tell you that this full committee did recommend, with your help, Mr. Chairman—

Mr. ROEMER. But your idea, Mr. Thornton.

Mr. THORNTON. I just supported a good idea.

But we do have some resources there now, and it is going to be my aim to try and get this kind of program going, if we can possibly do so.

Mr. ROEMER. Dr. Guile.

Dr. GUILE. Just one quick question or comment. I hate to be a small voice in favor of chaos. I mean I do believe that strategy is important, and I think it is important to think through as carefully as possible the technological futures and market futures we are going to have to deal with.

I'd also point out that you need some driving goal, single, simple statement, and I think that the primary one in terms of strengthening U.S. capability from the policy perspective is the integration of domestic technology policy with international trade questions, international standards questions, and intellectual property questions. That whole package of stuff has largely been dealt with by two different communities in this country, sometimes in the executive branch, sometimes in Congress, and it really needs to be integrated if we are going to be a global player on an ongoing basis.

Mr. ROEMER. That is perceptive, and hopefully that will lead into another set of hearings, possibly, that Chairman Valentine will be here personally to facilitate and conduct and orchestrate.

Mr. Thornton, do you have any concluding comments?

Mr. THORNTON. Just an excellent hearing, Mr. Chairman, and you really conducted yourself in an exemplary way.

Mr. ROEMER. Well, thank you. You and I could sit here and exchange compliments all day long, but we won't do that. I would just like to sum up by saying, once again, thank you to the distinguished panel for your expert testimony, also for your interesting comments upon your own personal perspectives, bringing different exhibits to the testimony as well this morning, and I would like to encourage all four of you not to have your testimony stop today, that you work with the chairmen, Chairman Valentine and Chairman Brown, who are doing great things on this committee to see that this competitiveness issue is addressed, that you work with myself and Mr. Thornton, that we always have an open door to you, and that we look for ways by which we develop an overall strategy and system and address what is, I think, one of the biggest problems this country faces, and hopefully the next set of hearings might look at not so much trade politics that we engage in but a trade policy that we can engage in.

Thank you very much, gentlemen, and we look forward to working with you in the future.

Mr. ELKUS. Thank you.

[Whereupon, at 12:05 p.m., the subcommittee was adjourned.]

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